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VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA
THOMAS LEONARD WATSON, PH. D.
DIRECTOR

Bulletin No. V

THE

Underground Water Resources

OF THE

Coastal Plain Province
of Virginia

BY
SAMUEL SANFORD

PREPARED IN COÖPERATION WITH THE
UNITED STATES GEOLOGICAL SURVEY

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UNITED STATES GEOLOGICAL SURVEY

CHARLOTTESVILLE
UNIVERSITY OF VIRGINIA

1913



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STATE GEOLOGICAL COMMISSION

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Governor of Virginia.

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Member of the House of Delegates.

THOMAS LEONARD WATSON,
Director of the Survey.

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LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, December, 1912.

*To His Excellency, Hon. Wm. Hodges Mann, Governor of
Virginia, and Chairman of the State Geological Commission.*

SIR:—I have the honor to transmit herewith for publication, as Bulletin No. V of the Virginia Geological Survey Series of Reports, a report on "The Underground Water Resources of the Coastal Plain Province of Virginia," by Mr. Samuel Sanford of the U. S. Geological Survey.

This report has been prepared by the Virginia Geological Survey in coöperation with the U. S. Geological Survey and should prove of much value to the Tidewater section of Virginia. It forms a companion volume to Bulletin No. IV, entitled "The Physiography and Geology of the Coastal Plain Province of Virginia," published by the Virginia Geological Survey in January, 1912.

Respectfully submitted,

THOMAS L. WATSON,
Director.

UNDERGROUND WATERS OF THE COASTAL PLAIN PROVINCE OF VIRGINIA

BY SAMUEL SANFORD.

INTRODUCTION

Scope of Report.—This report deals with an investigation of the underground waters of the Coastal Plain Province of Virginia, a tract of country some 9,500 square miles in extent, which roughly corresponds with what has been known since Colonial times as Tidewater Virginia. The purposes of the investigation were to continue the study, begun by Darton, of the artesian waters of the Coastal Plain, and to examine the waters obtainable by open wells. Thus this report covers the occurrence and character of both shallow and deep waters; the geological relations of water beds; extent of artesian horizons and areas in which flowing wells can be had; methods and costs of developing underground water supplies; special adaptability of waters for domestic or medicinal use, and their application in agricultural and other industries; the relation of well and spring waters to the public health with particular reference to water-borne diseases; in short, the report is intended to answer those questions relating to underground water that would be most likely to occur to any one interested in the subject, whether resident, homeseeker, or promoter of industrial enterprises.

The facts presented were collected through correspondence with postmasters, drillers, and well-owners, and through field work. The correspondence includes the data received in answer to circular letters sent out in 1905. The field work was done by the writer in 1906, 1909, and 1910, chiefly in the fall of 1906.

Acknowledgments.—The writer is under obligations to N. H. Darton, geologist, U. S. Geological Survey, for hitherto unpublished data relating to a number of wells mentioned in the text. Grateful acknowledgment is made of suggestions from M. L. Fuller, formerly geologist, U. S. Geological Survey, regarding particular questions that came up in the progress of field work; and to many well drillers, especially J. H. K. Shannahan, Easton, Md.; R. H. Milligan, Crisfield, Md.; O. D. Hale, Whealon, Va.; I. B. Clark, Accomac, Va.; L. Rude, Tilghman, Md.; S. H. Fetterhoff, Achilles, Va.; H. E. Shimp, Cappahosic, Va.; J. W. T. Robertson, White Haven, Md.; and J. V. Bray, West Point, Va., for information

regarding wells and the occurrence of artesian waters. Acknowledgment is also made to Froehling and Robertson of Richmond, Va.; W. H. Taylor of Richmond, Va.; the H. Bentley Smith Company of Philadelphia, Pa.; and the Sparrow's Point Boiler Company of Baltimore, Md., for kindly furnished copies of analyses of well waters. Many of the analyses were submitted to R. B. Dole and Chase Palmer of the U. S. Geological Survey, for recomputation to express results in the form adopted by the Federal Survey. Finally, the writer thanks the hundreds of persons who gave information regarding particular wells.

Literature.—Though many references to the wells and springs of Tide-water Virginia appear in narratives of travelers, in descriptions of various points of interest, and in accounts of military campaigns, the literature distinctly relating to underground waters is scanty, and is largely confined to the writings of Darton. His contributions comprise a paper before the American Institute of Mining Engineers,^a a bulletin on Artesian Prospects in the Atlantic Coastal Plain,^b and mention of underground waters in the Washington, Fredericksburg, Nomini, and Norfolk folios, Nos. 13, 23, 70, and 80, respectively, of the Geologic Atlas of the United States. By far the most important one of these is the bulletin on artesian prospects. It reviews the geologic relations of the water beds, contains a number of well records, many of which are reproduced in this report, and briefly indicates the outlook for artesian water in each of the Coastal Plain counties. Fuller and Darton^c re-stated Darton's views in Water Supply Paper, No. 114, and Fuller summarized his own conclusions in a paper before the American Waterworks Association.^d The conclusions of Darton and Fuller, chiefly those expressed by Darton in Bulletin No. 138 of the U. S. Geological Survey, have been briefly summarized by Watson^e in a volume prepared for the Virginia Jamestown Exposition Commission.

The underground waters of the St. Mary's quadrangle, which includes a very small portion of Westmoreland County, are discussed by B. L. Miller in Folio No. 136 of the United States Geological Survey.

^aDarton, N. H., Artesian Well Prospects in Eastern Virginia, Maryland, and Delaware, Trans. Amer. Inst. Min. Engs., 1905, vol. 24, pp. 372-397.

^bDarton, N. H., Artesian Well Prospects in the Atlantic Coastal Plain Region, Bull. U. S. Geol. Survey No. 138, 1896, pp. 162-190.

^cFuller, M. L., and Darton, N. H., Underground Waters of Eastern United States, U. S. Geol. Survey, Water Supply Paper No. 114, 1905, pp. 127-135.

^dFuller, M. L., Artesian Waters of the Atlantic Coastal Plain, Amer. W. W. Ass'n, 1907.

^eWatson, T. L., Mineral Resources of Virginia, 1907, pp. 268-275.

The publications mentioned deal chiefly with geologic conditions and particularly with artesian water; references to the composition of the waters are largely limited to an occasional analysis. W. B. Rogers^a in his report for 1835 gives an analysis of a spring at Williamsburg. In the Norfolk Folio, Darton gives analyses of the water from two flowing wells. Fontaine^b has mentioned an alum spring near Fredericksburg. Peale, in Bulletin No. 32 of the U. S. Geological Survey, gives the analysis of a spring near Richmond. Haywood, in Bulletin No. 91 of the U. S. Bureau of Chemistry, gives a detailed analysis of a spring in Alexandria County. Froehling and Robertson^c have published analyses of five springs, two of which are mentioned by Watson in the report already cited; and Fuller, in his paper before the American Water Works Association, briefly refers to the quality of the water from different horizons, and the general character of the mineralization.

Nowhere, so far as the writer is aware, have the characteristic features of the artesian waters of most of the Virginia Coastal Plain been discussed at length.

Results of investigation.—The study of the Coastal Plain formations in Virginia, the examination of springs and wells, and the analyses of the waters, have shown that plenty of water is to be had, and except in a limited area in the southeastern and eastern part of the Coastal Plain artesian supplies of abundant flow and excellently adapted for domestic purposes can be obtained without difficulty. Enough deep wells have been sunk to prove the existence of several widely extending series of beds containing water-bearing sands, and it is possible to say at what depth, at most localities, a particular series of beds can be found.

Dug wells are so cheaply sunk that they have become the main source of domestic supply. Many such wells from their location and the insufficient precaution against the entrance of water contaminated by organic wastes may frequently become dangerous to the public health. But dug wells properly located and protected will, in many places, yield entirely satisfactory supplies. The deposits underlying the terraces on which stand many of the towns and villages of the Coastal Plain transmit water readily, hence springs issuing from such terraces or shallow wells in the villages are easily polluted by filth from vault privies and from cesspools.

^aRogers, W. B. A reprint of Annual Reports and other papers on the Geology of the Virginias. 1884, p. 40.

^bFontaine, W. M. The Potomac Formation in Virginia, Bull. U. S. Geol. Survey No. 145, 1896, p. 68.

^cFroehling, Henry, and Robertson, Andrew. A hand-book prepared for the Virginia Commission to the St. Louis Exposition, 1904, pp. 97-159.

The mineral content of the well and spring waters varies greatly at different localities, or even in the same locality, hence both the deep and the shallow waters are variously suitable for domestic use, boiler supply, or particular industries. The most striking characteristic of the artesian waters of certain formations on the west side of Chesapeake Bay is their relatively large content of sodium bicarbonate. In this aspect they differ from many deep waters.

TOPOGRAPHIC AND GEOLOGIC PROVINCES OF VIRGINIA

General statement.—The State of Virginia includes parts of three great topographic and geologic provinces which have been traced from New York to Georgia. In Virginia they are called the Allegheny Ridges, the Great Valley, the Blue Ridge region, the Piedmont Plateau, and the Coastal Plain. The approximate boundaries within the State of these provinces are indicated on the accompanying map. The two last are the only ones considered in this report. Because of the relations between these two provinces, certain features of the Piedmont Plateau are briefly mentioned here.

PIEDMONT PLATEAU

General description.—The Piedmont Plateau is a rolling plain that slopes gently eastward from the Blue Ridge mountains to where the hard rocks which underlie it are overlapped by the relatively unconsolidated deposits of the Coastal Plain. Where this plain now lies were once lofty hills and mountains, but weathering and the erosive action of the wind and the streams has reduced all great inequalities of surface. Since the deposition of the Coastal Plain sediments began, the area has been elevated, eroded, depressed and slightly tilted several times. It now stands higher than it did a geologically short time ago. The Piedmont rivers are actively deepening their channels, and are swift-flowing and unnavigable.

The rocks of the Piedmont Plateau comprise crystalline masses, granites, gneisses, and schists. The granites and some of the gneisses and schists crystallized from a molten state, but others of the gneisses and schists were once beds of sand and clay which after consolidating to hard rock lost all trace of original structure by mountain-building stresses in time long past. The ages of these rocks range from pre-Cambrian to Silurian. Among the crystalline masses are detached areas of comparatively little altered rocks, reddish, purplish and greenish sandstones, conglomerates and shales, intersected and parted by intrusions and flows of diabase, a heavy dark-greenish crystalline rock. These sedimentary beds and the diabase are of Triassic age, and the former belongs to the Newark series.

The eastward extent of the Piedmont rocks is unknown. They underlie the Coastal Plain and can be reached anywhere in Tidewater Virginia by wells of sufficient depth.

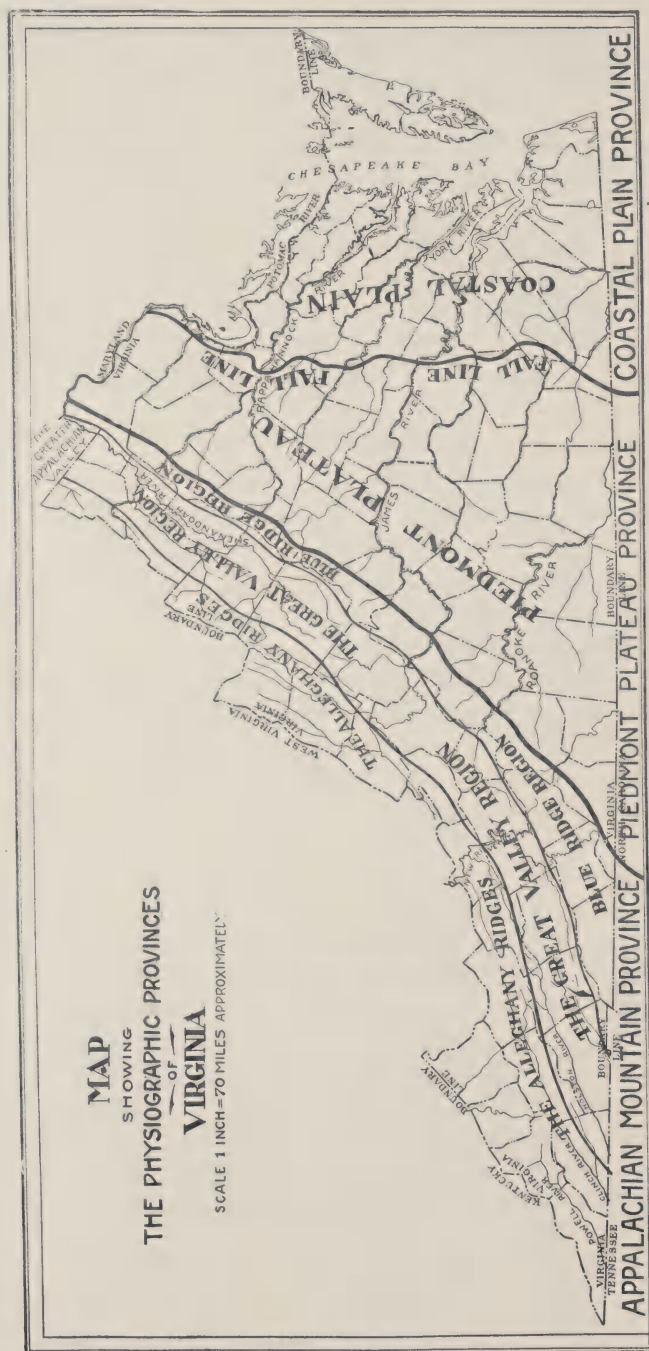


Fig. 1.—Sketch-map showing physiographic provinces of Virginia.
(After Watson, Mineral Resources of Virginia, 1907, p. 2.)

COASTAL PLAIN

General description.—Seaward from the Piedmont extends the lower-lying Coastal Plain characterized by its sluggish tidal rivers, stretches of flat land, and absence of hard rocks. Under the ocean the Coastal Plain beds reach the edge of the Continental shelf, a hundred miles off the Virginia coast.

Gravels, sands, clays, loams, and shell marls make up the great bulk of the Coastal Plain deposits in Virginia. In places some of the sands have been consolidated to sandstones and the clays to shales; in places, also, are shell beds so compact as to form lime rock, but there are no extensive areas of heavy-bedded limestones, such as are found in the Coastal Plain of North Carolina and of the states farther south. The “rocks” reported by drillers are mostly thin, irregular layers of limited extent. Some apparently are compacted shell beds but many are streaks or lumps of indurated sand in which the individual grains are cemented by silica or lime. The maximum thickness of the Coastal Plain formations in Virginia has not been determined. It may exceed 2,500 feet.

GEOGRAPHIC POSITION

The Coastal Plain of Virginia lies east of a line running through Emporia, Petersburg, Richmond, Fredericksburg and Alexandria, this line, from Emporia to north of Fredericksburg, corresponding nearly with the meridian of $77^{\circ} 25'$. Its length from the North Carolina line to the Potomac River at Alexandria is 185 miles. The maximum width, from Assateague Island to west of Milford, is about 115 miles. The total area is about 9,500 square miles.

CLIMATE

The climate of Tidewater Virginia is mild; nearness to the ocean tends to temper extremes of heat and cold. The following table gives mean annual temperatures for varying terms of years at a number of places, together with the mean monthly maximum and minimum temperatures.

Temperatures in Tidewater Virginia.

(Degrees Fahrenheit.)

Place	No. years obs. made	Mean annual	Month of maximum	Month of minimum
Ashland	15	56.7	July 77.7	Jan. 35.3
Cape Henry	32	58.7	" 77.0	" 40.2
Fredericksburg	17	55.8	" 77.5	Feb. 33.3
Hampton	23	58.9	" 79.2	" 39.9
Norfolk	36	59.0	" 78.5	Jan. 41.1
Petersburg	19	57.9	" 77.7	" 37.6
Quantico	9	54.1	" 77.4	Feb. 28.6
Richmond	27	58.0	" 78.2	Jan. 38.0
Spottsville	18	57.3	" 77.9	" 37.8
Warsaw			" 78.0	
Williamsburg	15	56.3	" 78.0	Feb. 34.6
Washington, D. C.	36	56.3	" 77.3	Jan. 33.2

The climate is humid and the rainfall, which is so distributed through the year so as to favor the growth of vegetation, is abundant. The mean annual precipitation varies from 52 inches in the southeastern part of the province to 41 inches in the northwestern. The larger part of the precipitation is in the summer and spring, and comparatively little is in the form of snow.

The accompanying table shows the average precipitation at a number of places for various terms of years, and also the quarterly periods in which precipitation is greatest and least.

Precipitation in Tidewater Virginia.

Place	No. years obs. made	Mean annual	Mean quarterly maximum		Mean quarterly minimum	
		Inches	Quarter	Inches	Quarter	Inches
Ashland	15	41.75				
Cape Henry	32	52.34	Jul.-Sept.	15.72	Oct.-Dec.	11.21
Fredericksburg	15	42.25				
Hampton	23	43.60				
Norfolk	36	52.08	Jul.-Sept.	16.59	Oct.-Dec.	10.64
Petersburg	19	44.49				
Richmond	35	44.09	Jul.-Sept.	13.60	Oct.-Dec.	8.87
Spottsville	17	49.12				
Williamsburg	11	45.86				
Washington, D. C.	36	41.32	June-Aug.	12.57	Oct.-Dec.	9.36

A map (Chart 12) issued by the United States Weather Bureau from which the accompanying sketch map was made, shows how the rainfall diminishes in a northwest direction across Tidewater Virginia.



Fig. 2.—Sketch-map showing distribution of rainfall in eastern United States.
(From U. S. Geol. Survey Water Supply Paper 223, p. 8.)

TOPOGRAPHY

General description.—The average seaward slope of the surface of the Coastal Plain of Virginia is about three feet to the mile. This slope is enough to cause rapid-flowing rivers, but the Coastal Plain rivers are sluggish because they flow through valleys that have been drowned by a recent depression of the land. Chesapeake Bay that crosses the eastern part of the plain from north-northwest to south-southeast is the drowned valley of a greater Susquehanna River that once flowed across the now submerged part of the plain to reach the ocean, then far east of the present shore line. Potomac, Rappahannock, and James rivers, the principal tributaries of Chesapeake Bay, are tidal estuaries to the western edge of the plain. Here the exposed crystalline rocks make rapids in the rivers; this zone of rapids has been called the "fall-line." Because sea-going vessels could not go farther inland, trading posts were established near the rapids on the different rivers in the early years of the colony, and these settlements have grown to the cities of Alexandria, Fredericksburg, Richmond, and Petersburg.

Terraces or terrace plains.—The seaward slope of the Coastal Plain, though gentle and as a whole uniform, is, in detail, step-like, broad terraces separated by more or less sharply defined scarps running along the river valleys and around intervening divides. The higher of these terraces or terrace plains, being oldest, are the more eroded; along river valleys and on narrow divides they have acquired a rolling surface and are sharply incised by the gorges of streams that head in springs or swamps. The lower and younger terraces have suffered less from stream attack. Near tide level in places the lowest terrace grades into salt marshes; inland in places it carries fresh water swamps, of which Dismal Swamp, lying on its widest portion, is the largest.

Topographic types.—Because of the varying elevation and width of these terraces and their manner of dissection, three types of topography may be distinguished in Tidewater Virginia. They are here designated as the eastern shore, the western shore, and the North Carolina.

The eastern shore topography is characterized by the low relief, under 50 feet, the slight erosion, and the gentle slope of the land toward tide level. Salt marshes fringe long stretches of the coast and tidal creeks reach inland up shallow channels.

The topography of the western shore is far more varied. Because of the narrow divides between the valleys of the Potomac, Rappahannock, York,

and James rivers, and because along these rivers near the "fall-line" the highest of the terraces lies 200 to 400 feet above tide level, there are high cliffs and steep descents. The larger tributaries of the rivers have cut back into the divides. Their upper courses, locally called branches or runs, flow rapidly through narrow V-shaped valleys or shallow gorges, while the tidal lower courses, known as creeks, cross the youngest terrace by shallow partly drowned valleys. In places one terrace or another has been cut out by the rivers, so that here and there toward the fall line bluffs, or scarps, over 100 feet high mark the drop from a high terrace to tide level or the lowest terrace.

The part of the Coastal Plain south of James River has topography of the North Carolina type; that is, it resembles the topography of the northern portion of the North Carolina Coastal Plain. The stream valleys of the higher terraces are more open and have lower gradients than to the north; maximum elevations are less; the lower terraces are more extensive. The general slope of the surface is southeast and the rivers flow to the sounds of North Carolina. The above differences in topography determine differences in the occurrence of underground waters.

GEOLOGIC RELATIONS OF COASTAL PLAIN DEPOSITS

General description.—The generally unconsolidated deposits of the Virginia Coastal Plain rest on a floor of crystalline rocks that dips seaward. The beds just above bed-rock have an average inclination of about 30 feet to the mile; those laid down last dip 5 feet or less to the mile. Beds with steeper dips, 20° to 40° , have been noted in some of the formations, but such dips are local. The decrease in the dip from below upwards is a result of the initial seaward slope of the crystalline rocks and subsequent elevations and depressions. A succession of swings complicated by gentle bowings or warpings of the bed-rock has alternately carried the coast-line far to the eastward or brought it westward of its present position, so each great series or group of beds has been laid down on the beveled edges of the series below. As the tiltings have varied in direction, the overlap of one series has swung across the general strike of the beds in the preceding series, and as some formations overlapped unevenly eroded surfaces the boundaries on the west are quite irregular.

Thickness of deposits.—The maximum total thickness of the succession of formations is unknown. The deep well at Fort Monroe passed through 2,242 feet of beds; but the total thickness on the Eastern Shore is probably

greater. At the big bend of Potomac River, northeast of Fredericksburg, the "fall-line"—the boundary between the Piedmont Plateau and Coastal Plain—curves to the east and takes a north-northeast course past Alexandria, Washington, and Baltimore. This may indicate a bowing of the crystalline rocks into a broad trough having an axis that dips southeast. Hence it is possible that at Franklin City, a well would go through 3,000 feet of sediments before reaching bed-rock.

CRYSTALLINE ROCKS

Character and extent.—The crystalline rocks along the western edge of the Coastal Plain comprise an extremely old (pre-Cambrian) series of gneisses, that originally were probably of igneous origin, intersected by intrusions of later granite, and large masses of gneisses and schists of doubtful origin, and age, though sedimentary in part and as late as upper Ordovician. These later gneisses and schists, like the older rocks, have been cut by igneous intrusions and the entire crystalline complex has been so mashed by pressure metamorphism, that much of the original structure has been obliterated and a complex system of folds and faults confuses rocks of widely different age and origin.

Slightly altered Triassic sandstones and shales with associated intrusions and flows of diabase underlie the Coastal Plain near Doswell and Ashland, but have not been found by deep borings elsewhere. This, however, is not surprising in view of the few holes sunk to bed-rock outside the immediate vicinity of Richmond and the probable limited extent of the Triassic rocks. The submerged portion of the Coastal Plain, which extends 100 miles east of the present shore line, is presumably underlain by crystalline rocks like those above described.

Bed-rock topography.—The Piedmont Plateau once extended far east of its present boundary as an undulating plain, in which scattered hills represented rock-masses that had best withstood the wear of wind and rain. The streams had reached their limit in down-cutting, and the bed-rock was deeply mantled with the products of decay. By a seaward tilting in early Cretaceous time, this mantle was worked over by streams and laid down as beds of sand, gravel, and clay. Since then earth movements have gently warped the crystalline floor into broad open troughs in some of which the succession of sediments is hundreds of feet thicker than on the ridges between. Hence, as the present rock-floor represents an original irregular rock surface, modified by what bending has taken place since sedimentation began.

depths to bed-rock vary at points equally distant from the "fall-line." The Fort Monroe record of 2,242 feet shows the average seaward slope between the well and the nearest point where crystalline rocks outcrop is 33 feet to the mile, but the slope is probably steepest near the "fall-line." North of Richmond, particularly along Potomac River, bed-rock slopes coastward at a greater rate, and a fall of 100 feet to the mile is indicated by the records of wells at Alexandria. This increase may mean that there has been faulting of the crystalline rocks near the "fall-line" north of Fredericksburg."

WATER SUPPLIES

The crystalline rocks carry more or less water and along the western edge of the Coastal Plain deep wells have been drilled in them. The conditions governing the occurrence of water in crystalline rocks and in unconsolidated materials are so unlike, that the chief characteristics of the crystalline rocks as water bearers and the quality of their waters are discussed in a separate chapter (pages 83-97).

Although under special conditions water may travel through crystalline rocks for considerable distances, in general its circulation is limited. Where crystalline rocks are buried by water-filled porous beds, they contain, near the porous beds, water of the same general character as the latter. Hence it is not to be expected that wells sunk far east of the western margin of the Coastal Plain will obtain good water if the overlying unconsolidated beds carry water that is not potable.

"Darton, N. H., Later Formations of Virginia and Maryland, Bull. Geol. Soc. Amer., vol. 2, p. 448.

SEDIMENTARY DEPOSITS

CRETACEOUS

LOWER CRETACEOUS

POTOMAC GROUP

Extent and character.—Immediately overlying the crystalline rocks throughout nearly all Tidewater Virginia is a great succession of gravels, cobble beds, sands, and clays classed as the Potomac group. This is exposed in stream gullies and railroad cuts along the western edge of the Coastal Plain from Alexandria to Fredericksburg, near Doswell, and in the valleys of James and Appomattox rivers south of Richmond and east of Petersburg. The smoothly rounded cobbles are of quartz, or dense vitreous quartzite, some dark, some light; cobbles of igneous rocks are rare. The sands frequently contain grains of feldspar, and where the feldspar grains are associated with angular quartz grains the sand becomes an arkose. The clays show great variety of color and texture. The proportion of coarse material is larger near the bottom of the succession of beds than near the top; also, the upper clays are often rather highly colored, red, yellow and brown, while those toward the bottom have more subdued tints, gray and dark green. The sands of the Potomac group, notably in exposures near Richmond and Petersburg, contain countless balls of clay that vary in diameter from an inch to a foot or more. They lie scattered through the sands and are even jumbled among hard quartzite boulders of equal diameter. Besides these balls the sands in places contain large sharply angular masses of clay that appear to have been torn from some bed. Sand and gravel beds compacted enough to make stone suitable for building rough walls are found on Aquia Creek and Appomattox River.

The Potomac beds show such local irregularities of dip that estimates of thickness based on dip can not be exact. It is probable that fully 350 feet of beds are exposed near Fredericksburg and at least 300 feet on Appomattox River. Under cover to the east, as shown by deep borings, the group thickens decidedly. The well at Fort Monroe went through 1,400 feet of material classed as Potomac by Darton.

The elevation of the lowest visible beds varies from sea-level at the "fall-line" to 250 feet in the divides between Potomac and Aquia creeks, Stafford County, and 300 feet on the hills northwest of Alexandria. The average eastward dip of the beds is from 30 to 60 feet to the mile.

The most striking characteristic of many Potomac outcrops is the heterogeneous mixture of materials. The sands are prevailingly cross-bedded; in places the minor beds are steeply inclined, but no bed is persistent for any great distance, and sections a few hundred feet apart in bluffs or railroad cuts show little correspondence. North of Fredericksburg and in the vicinity of Mount Vernon the upper part of the group is more evenly bedded.

Origin.—The fossils indicate that the Potomac beds as a whole were fresh water deposits and the varied aggregation of material in the lower beds shows that they were laid down by swiftly-moving currents. The fossils are mostly plant remains, impressions of leaves and seeds, with here and there lignitized or silicified wood. The animal remains include bones of dinosaurs.

DIVISIONS

The Potomac beds were first differentiated by W. B. Rogers^a 70 years ago; he noted their composition and determined closely the boundaries of their outcrops. Since then they have been studied in greater or less detail by Fontaine, McGee, Ward, Darton, Clark, Bibbins, Miller, and Berry, and have been variously subdivided. Owing to the varying composition of the beds, distinctions based on lithologic character have proved unsatisfactory. On the basis of plant remains the Potomac in Virginia is divisible into two formations, an older and a younger. The older is known as the Patuxent and the younger as the Patapsco, from the typical exposures on Patuxent and Patapsco rivers in Maryland.^b

Patuxent formation.—This, the lower of the formations, is traceable along river valleys near the "fall-line" from Alexandria to Petersburg. It comprises beds of cobbles, gravels and sands with discontinuous beds and lenses of clay and scattered clay balls. The sands are arkosic and cross-bedded. The clays are usually gray, drab, dark green, or chocolate in color. The fossils include plant remains of early Cretaceous types and bones of dinosaurs that have Jurassic affinities. The total thickness exposed north of Fredericksburg may be 250 feet. The formation dips east 30 to 60 feet to the mile.

Patapsco formation.—This formation has been recognized north of Fredericksburg and near Mount Vernon. South of Fredericksburg it is absent or is overlapped by Eocene and Miocene deposits. The Patapsco is

^aRogers, W. B., *The Geology of the Virginias*.

^bClark, W. B., and Bibbins, A., *Jour. Geol.* 1897, vol. 5, pp. 479-506.

clayey rather than sandy. The clays are bright-colored, and thicker and more evenly stratified than those in the Patuxent. The sands are less arkosic. The fossils comprise plant remains of Lower Cretaceous types. The exposed thickness of the Patapsco beds may be 150 feet. The formation dips east about 30 feet to the mile.

WATER SUPPLIES

Sandy beds in the lower formation of the Potomac group, the Patuxent, underlie almost all the Coastal Plain of Virginia and constitute vast reservoirs of water, but as they are deeply buried a short distance east of the "fall-line," making their development expensive, only a few wells draw on them. Most of these wells are near Alexandria. Near their outcrops the lower Potomac sands usually yield excellent water. Sands toward the top of the Patuxent seemingly are not so sure to yield good water. Far to the east the supplies become more mineralized and in the Norfolk area are too salty to be potable.

The significance of the disorder of the Patuxent sands to the well driller or geologist is that predictions of striking water at a given depth at a given place are little better than guess-work unless the records of near-by wells are known. Even then close estimates may be erroneous. Usually the best that can be done is to give the probable depth to a succession of sandy or gravelly beds, some one of which should carry satisfactory supplies.

UPPER CRETACEOUS

The Upper Cretaceous does not outcrop in Virginia. The outcrops of Coastal Plain deposits show a well-marked break above the highest beds of the Potomac group. Formations belonging to the Pamunkey (Eocene) and Chesapeake (Miocene) groups cut across the feather edges of the Potomac formations from the northeast. In Maryland and in North Carolina beds of Upper Cretaceous age, sands, clays, and greensands, intervene between the Lower Cretaceous and the Eocene deposits. As these beds have not been recognized in Virginia in wells less than 30 miles east of the "fall-line," their extent under cover in this State is conjectural. However, the Magothy formation is found on the heights back of Anacostia, D. C., across Potomac River from Alexandria, and the Raritan a few miles farther east. Upper Cretaceous beds were penetrated by deep wells at Crisfield, Md., Fort Monroe and Norfolk, Va. Back of Anacostia the Magothy may be 40 feet thick. Data for estimating the thickness of the Upper Cretaceous formations under cover far eastward are not particularly

reliable. Darton thought there were 60 feet of Magothy and 35 feet of higher Cretaceous beds at Crisfield, Md., and 120 to 140 feet of "Marine Cretaceous" beds at Fort Monroe and Norfolk.

The Raritan formation of Maryland includes clays much like those of the Patapsco with interstratified sands. The Magothy is of more variable composition. The Upper Cretaceous material from the deep wells of Crisfield, Md., included greensands, fine gray micaceous sands, and dark clays. In the Norfolk-Fort Monroe area the Upper Cretaceous deposits comprise gray micaceous sands, dark gray, red and green clays, and gray sandy clays. Upper Cretaceous fossils have been found north of Fort Monroe by deep wells near Selden, Gloucester County, and Fairport, Northumberland County.

TERTIARY

EOCENE

PAMUNKEY GROUP

Extent and character.—Along Potomac River between Aquia Creek and Matthias Point; on the divide between Potomac and Rappahannock rivers; along the latter from 3 miles southeast of Fredericksburg to 4 miles east of Port Royal; on Mattaponi River above Marricossick Creek; on the Pamunkey from Hanover to Piping Tree Ferry; on James River from Richmond to Coggins Point; and on the Appomattox between Petersburg and City Point, are exposures of sands, sandy marls and clays that contain abundant marine fossils, mostly shells of mollusks. The clays below tide-level are prevailingly dark-colored, usually greenish, but one, exposed in outcrops north of Fredericksburg and found by artesian wells along Potomac and Rappahannock rivers, is reddish to white. The sands range in color from light gray through bluish and greenish shades to almost black; many are composed of quartz grains with a varied proportion of the small irregularly-rounded dark green or black nodules of the mineral glauconite, a silicate of potash and iron. When these glauconite grains predominate the material becomes a greensand or what well drillers term "black sand."

In the sands are indurated streaks or nodules that form dense hard rock; these streaks are of irregular thickness and small extent. There are also hard beds composed largely of shells. At the base of the Pamunkey is a thin but rather persistent bed of dark pebbles or small cobbles.

The contact between the Potomac and the Pamunkey near the "fall-line" in places is decidedly uneven. There is evidence near Richmond and

Petersburg, where there are inliers of Pamunkey among hills of Potomac material, that the Pamunkey was laid down on an irregularly eroded surface having almost as much relief as the present topography. The total thickness of the Pamunkey beds exposed on Potomac River is 225 feet. Unlike the Potomac group, the Pamunkey does not thicken greatly under cover, and it thins out to the southwest. The well at Crisfield, Md., penetrated possibly 150 feet of it; the borings at Fort Monroe and Norfolk not over 250 feet and possibly less than 100 feet. South of Petersburg to the North Carolina line there are no definitely identified exposures of Pamunkey beds.

Since deposition the Pamunkey beds have been slightly tilted and now dip 10 to 15 feet to the mile east. Above water-level, owing to the proportion of iron in the glauconite and the easy decay of the mineral, the Pamunkey sands weather to shades of brown, buff and yellow; the clays also grow brighter, buff being perhaps the color most frequently seen in high-lying exposures.

DIVISIONS

Clark, who has described the Pamunkey in Maryland and along Potomac River in Virginia, divides the group into two formations, the Aquia and the Nanjemoy, of which the Aquia contains the greater proportion of sandy beds and the Nanjemoy the more clay. For a detailed account of the Potomac River exposures the reader is referred to reports of the Maryland and Virginia Surveys.^a

Aquia formation.—This formation is typically exposed along Aquia Creek in Stafford County, where it is 100 feet thick. It comprises beds of greensand and greensand marls containing many marine shells of Eocene age. Southward it thins out, is overlapped by the Nanjemoy, and is exposed in few Pamunkey outcrops south of Richmond.

Nanjemoy formation.—This formation, named after Nanjemoy Creek in Maryland, outcrops in river valleys from the big bend of Potomac River to Petersburg. It does not outcrop further south and at the North Carolina line its western boundary may be 30 miles east of Emporia. It comprises beds of sand, greensand and clay, with numerous marine shells. A distinctive bed of clay, white at the top, pink at the bottom, marks the base on the divide between Potomac and Rappahannock rivers near Fredericksburg, and has been recognized in wells along those rivers to the east. The total thickness of Nanjemoy beds exposed on Potomac River is about 125 feet.

^aClark, W. B., Maryland Geol. Survey. Eocene, 1901, pp. 59-71; Clark, W. B., and Miller, B. L., Bull. No. iv, Virginia Geol. Survey, 1912, pp. 93-96.

Brief descriptions of the Pamunkey beds under cover, as reported by drillers, are shown in the well records published on succeeding pages.

WATER SUPPLIES

Under much of Tidewater Virginia the Pamunkey group is an important source of deep water, though the porous sands which give flowing wells are relatively thin and few in comparison to the total thickness of sandy material and the number of sand beds seen in the outcrops. The glauconite sands, because of the proportion of interstitial space between the rounded granules of glauconite, give up water more easily than quartz sands and such open-textured beds full of the dark green or black glauconite are called "water sands" or "true water sands" by well drillers.

MIOCENE

CHESAPEAKE GROUP

Extent and character.—The irregular edge of the Chesapeake cuts across the Potomac and Pamunkey beds in a south-southwest direction, and south of Rappahannock River to the North Carolina line the Potomac and Pamunkey are exposed only in river valleys. On the divides the western edge of the Chesapeake rests directly on the crystalline rocks. East of the line along which the Pamunkey beds slope below tide-level the Chesapeake deposits are hidden only by a thin covering of Columbia material and are exposed to river bluffs and in creek valleys nearly to Chesapeake Bay. Thus the area in which the Chesapeake outcrops is much greater than the combined outcrop areas of the Potomac and Pamunkey.

The Chesapeake beds are prevailingly sandy, with a varying proportion of clay. They comprise pure quartz sands, glauconitic sands, sandy clays, and beds of marl; the latter, full of tightly packed marine shells, are widely distributed. Some of the sand beds contain glauconite in scattered grains only, others are almost as glauconitic as those in the Pamunkey. Streaks and nodules of hard, cemented sand or "rock" occur at many horizons, but individually are of small extent. The colors below water-level are subdued, varying from light gray through bluish and greenish shades to dark greenish gray.

Near the base of the Chesapeake are drab and gray beds of clayey or finely sandy material full of the minute siliceous tests of diatoms, forming diatomaceous earth. In places, as just below Wilmont Landing on the Rappahannock, these diatomaceous earth deposits are 50 feet thick.

On exposure the Chesapeake beds weather to brighter tints, buff and yellow predominating. The elevation of the highest lying beds ranges from 250 feet back of Brooke, to about 100 feet near the Virginia-North Carolina line. The maximum thickness of the group in Virginia may be 700 feet. The dips are southeast and east, about 6 to 10 feet to the mile. In places comparatively steep reverse dips up to 30° are seen, but these are of small extent.

DIVISIONS

Four divisions of the Chesapeake, based chiefly on differences in the abundant marine fauna, have been recognized in Virginia by Clark; these are the Calvert, Choptank,^a St. Mary's and Yorktown. This fourfold division of the Chesapeake applies to the outcrops west of the bay. The relation of the formations far under cover in the eastern and southeastern parts of the State has not been established. Deep wells near Norfolk show a great thickness of dark, fine sandy clays and clayey sands, and few distinctive fossils that might serve as guides in correlating records have been saved in drilling.

Calvert formation.—This formation, the most clayey of the four, has been traced along the west edge of the Coastal Plain from Potomac River to south of Petersburg. Farther south it is overlapped by the St. Mary's. It is well exposed at several localities, notably the bluffs on Rappahannock River south of Port Conway. It contains thick diatomaceous earth deposits and shell beds with characteristic marine fauna. The maximum thickness exposed is 200 feet. The average dip is southeast and east about 10 feet to the mile. It is named from Calvert County, Maryland.

Choptank formation.—This formation is sandier than the Calvert but contains a considerable proportion of clayey beds as well as diatomaceous earth. It is not exposed anywhere in Virginia but may intervene between the Calvert and St. Mary's under cover in the Potomac Valley as it has been recognized and mapped in Maryland.

St. Mary's formation.—This formation consists of bluish and greenish sandy clays and gray sand, with many thick beds of shell marl. It is established as a separate formation by the predominance of certain marine shells. The thickness is 150 feet and the dip 8 or 10 feet to the mile eastward. It is named from St. Mary's County, Maryland.

Yorktown formation.—This formation succeeds the St. Mary's so conformably that no sharp dividing line has been determined. It is sandy,

^aNot recognized in Virginia by Clark and Miller, Bull. No. iv, Virginia Geol. Survey, 1912, p. 140.

richly fossiliferous, and at the type locality, Yorktown, contains firm, fairly hard rock made up almost entirely of comminuted shells. Its total thickness is over 100 feet. As a whole it slopes seaward at the rate of 6 or 8 feet to the mile, but in places are fairly steep westward dips.

WATER SUPPLIES

From its extent, stratigraphic position, and sandy character, the Chesapeake group is a notable source of artesian water. It has been tapped by many hundreds of inexpensive wells and its deep supplies, except on the eastern shore of Chesapeake Bay and in a few counties on the western shore, are soft, "light," fresh, and excellently suited to domestic use. The shallow waters may be hard from lying in beds of shells or iron-bearing from the decay of glauconite.

PLIOCENE (?)

No beds containing distinctive Pliocene fossils have been found in Tidewater Virginia. There are such beds in the Coastal Plain of North Carolina and of other states southward, notably Florida. The Lafayette has been classified as a Pliocene formation. The lithologic resemblances between the Lafayette and the Sunderland formation in Virginia are great and there is no definite proof that the Lafayette is older than Quaternary. It is here called Pliocene (?).

Lafayette Formation^a

Extent and character.—The Lafayette is a far-extending but relatively thin mantle of clay, sand, and cobbles, in which the finer-textured material has in places an orange or reddish tinge. This vast, blanket-like deposit, usually gravelly toward the base but loamy near the surface, has been traced along the higher portions of the Atlantic Coastal Plain from New Jersey to Florida and across the Piedmont to the Blue Ridge. It is characterized not only by the bright hues of its loams and clays but by the peculiarly irregular and confused arrangement of the materials in many of the coarser beds. The formation is high-lying, overlapping the Coastal Plain sediments only where they are much above sea-level, and nowhere in Virginia reaching tidewater, being cut off seaward or riverward by distinct slopes and well-marked scarps. Another peculiarity is a scarcity of fossils.

^aThe name Lafayette was proposed by Hilgard in 1891 from Lafayette County, Miss. Amer. Geol. 1891, vol. 8, pp. 129-131. Berry has recently shown that the so-called Lafayette of the type section in Lafayette County, Miss., is of Eocene age. Jour. Geol. 1911, vol. 19, pp. 249-256.

the organic remains being plant fragments and impressions of no determinative value. This far-spread mantle was first recognized as a distinct geologic unit by McGee^a and named by him the Appomattox formation.

The total extent of the formation in Virginia has not been determined. It covers little of the tidewater country. Its cobbles and gravels rest on the crystalline rocks of the Piedmont, or on the edges of Potomac, Pamunkey, or Chesapeake beds. Usually not over 50 feet thick and nowhere filling the gorges, the Lafayette caps the higher interstream plateaus. Its base is 480 feet above tide at Peach Grove Hill in Fairfax County, and 200 feet near Fredericksburg. Whether it actually is present at the type locality of McGee's Appomattox formation, southeast of Petersburg, is uncertain.^b

Along Potomac River north of the great bend the Lafayette is sharply interrupted or cut off by the river valley. South of the great bend to Petersburg the eastern limit of the formation is less clearly defined, but probably nowhere extends far east of the "fall-line." It has been traced inland back of Fredericksburg for 10 miles, and has been described by Shaler and Woodworth^c in the Richmond coal basin at altitudes of 350 feet.

Origin.—The probable origin of the Lafayette has caused much discussion. Some geologists have called it a marine formation, others have said it was formed by streams. Further investigation may show that the term Lafayette has been applied to both marine and fluvial deposits. A detailed discussion of the origin lies without the province of this report. In Virginia the field relations, varied lithology, heterogeneous assortment of materials, and lack of fossils, are evidence in favor of a fluvial or estuarine rather than a marine origin.

WATER SUPPLIES

The Lafayette gravels are reservoirs of ground water for springs and dug wells. The supplies they furnish are generally limpid and soft, and in some places remarkably low in mineral content but, from the limited extent of the Lafayette in the Coastal Plain, are important in only a few counties.

^aMcGee, W. J., Three Formations of the Atlantic Slope, Amer. Jour. Sci. 3rd ser., 1888, vol. 25, pp. 120-143.

^bThe writer is of the opinion that the Appomattox formation in the vicinity of Petersburg, as described by McGee, includes Columbia beds, and that the Lafayette has not been differentiated with exactness there.

^cShaler, N. S., and Woodworth, J. B., Geology of the Richmond Basin, Virginia, 19th Ann. Rept. U. S. Geol. Survey, Part 2, pp. 385-519.

PLEISTOCENE

COLUMBIA GROUP

Character and extent.—Over most of Tidewater Virginia, resting on Miocene, Eocene, or Cretaceous deposits, or on the crystalline rocks of the Piedmont, lies a mantle of loam, clays, sands, gravels and cobbles; the older strata cropping out on river bluffs, in stream gullies, and on eroded divides. Like the Lafayette, this mantle shows a prevailing assortment into coarse material at the bottom and fine at the top, and its component beds show great differences of color, texture, and arrangement. The clays have many hues, from dark gray through yellow or buff to orange and red; the coarse material comprises evenly stratified sands and mixtures of sands, cobbles, and boulders that seemed dumped in place.

The Columbia differs from the Lafayette in several details. While the latter mantled an undulating surface, the Columbia partly filled river gorges and capped intervening divides. The Lafayette forms a sloping plain cut off to the seaward and along river valleys by scarps or graded slopes; the Columbia comprises several terraces or terrace plains that slope seaward and toward river valleys. Large transported boulders are not found in the Lafayette, but are common on the river terraces of the Columbia toward the "fall-line." Some of these boulders are seven or eight feet long, have polished and striated faces, and have evidently been dropped by ice floes. The Columbia loams on the lower terraces are mostly light buff and yellow; on the higher terraces, buff and red; but south of James River bright-colored loams are not so common as along Potomac River. Even on the highest terrace they are often light buff and yellow rather than dark buff, orange, and red.

The landward elevation of the surface of the highest terrace along the "fall-line" varies from 300 feet west of Alexandria to about 150 feet south of Petersburg. The surface of the lowest terrace is less than 25 feet above tide and extends to sea-level in many places. The only fossils found in the clays of the higher terrace are plant remains. The lowest terrace contains plant remains and marine shells.

DIVISIONS

In Maryland, three terraces were distinguished by Shattuck^a and traced across the State. He found that while each terrace sloped seaward and

^aShattuck, G. B., *The Pleistocene Problem of the North Atlantic Coastal Plain*, Amer. Geol., 1901, vol. 28, pp. 87-107; Maryland Geol. Survey, Pliocene and Pleistocene, 1906, 291 pp. lxxv plates.

toward river valleys, there was a remarkable uniformity of elevation at points on the same terrace many miles apart. The three terraces he named in order of age, from high to low, the Sunderland, Wicomico, and Talbot, and classified their materials as the Sunderland, Wicomico, and Talbot formations. This division of the Columbia he extended into Virginia.

In North Carolina six terraces with elevations varying from sea-level to 200 feet have been described.^a Stephenson^b discriminates five Pleistocene terraces in North Carolina. The names he gives them and the elevations above sea-level are as follows, in order of age: Coharie, 160 to 220 feet; Sunderland, 110 to 160 feet; Wicomico, 60 to 90 feet; Chowan, 30 to 50 feet; Pamlico, 0 to 25 feet. The Coharie has not been recognized north of North Carolina. The Chowan and Pamlico together correspond to the Talbot of Maryland and Virginia as described by Shattuck.

Clark and Miller^c have recognized and traced three Columbia terraces in the Virginia Coastal Plain and have designated as formations the deposits that constitute them, the Sunderland, the Wicomico, and the Talbot.

The terraces as a whole slope east or southeast, but along the rivers each terrace slopes toward the river; on the divides the slope is seaward. Hence the elevation of each terrace is least toward the river or the ocean and greatest at the foot of the slope or scarp which marks the transition to the terrace above.

In general there is on each terrace a rough assortment of materials from coarse at the base, to fine near the surface. The proportion of very coarse material, gravel, cobbles and boulders, is greatest near the "fall-line." The basal sands are generally gray in color; the tints of the subsoil loams and clays range from dark gray with bluish, brownish or greenish hues, to bright red, orange and buff.

The thickness of each terrace formation varies from a thin edge near the scarp above to a maximum at varying distances riverward or seaward. The maximum thickness of the lowest formation is uncertain because in places on the western shore of Chesapeake Bay and along the bay side and ocean side of the Eastern Shore, a considerable part of the formation lies below tide-level and its materials have not been definitely distinguished from the Chesapeake (Miocene) beds on which they presumably rest.

^aJohnson, B. L., Pleistocene terracing in the North Carolina Coastal Plain, *Science*, 1907, vol. xxvi, pp. 640-642.

^bStephenson, L. W., *Geology and Underground Waters of the North Carolina Coastal Plain*, N. C. Geol. Survey. In press.

^cClark, W. B., and Miller, B. L., Bull. No. iv, Virginia Geol. Survey, 1912, p. 48.

Sunderland formation.—Maximum elevations of the Sunderland range from 300 to 220 feet on divides back of the "fall-line," to 90 feet at points along the rivers farther east. The Sunderland-Wicomico scarp extends along a northeast line, that is a line at right angles to the trend of the larger river valleys. The materials of the Sunderland terrace, which constitute the Sunderland formation, comprise cobble-beds, sands and gravels, bright-colored loam and clays, and near the "fall-line," large boulders. The thickness of the formation varies from a feather-edge to a maximum of 50 feet.

Wicomico formation.—The Wicomico terrace can be traced at intervals along the rivers to the "fall-line" and around the intervening divides from North Carolina to Potomac River. It is widest south of James River where it is 10 miles wide. On the divides between York, James, Rappahannock, and Potomac rivers, this terrace is not as pronounced a topographic feature as the terrace below it. The terrace materials comprise cobbles, gravel, sand, and bright-colored loams and clays, much like the Sunderland. The thickness varies from a feather-edge to about 45 feet.

Talbot formation.—The Talbot is the youngest and most easily distinguished of all the terraces.^a It is 30 miles wide at the south and includes all of Princess Anne County, most of Norfolk, nearly all of Elizabeth City County, the east end of Gloucester County, and practically all of Mathews County. Reëntnants of this terrace extend up the river valleys. On the eastern shore the terrace probably includes all of Northampton County and most of Accomac County. The Talbot formation is composed of sands, gravels, clays and loams, with cobbles and ice-borne boulders along the river toward the "fall-line." The fossils comprise cypress stumps and other plant remains, and beds of marine or brackish water shells. The thickness of the formation ranges from a few feet to fully 40 feet on the western shore of the bay. On the eastern shore the thickness may exceed 50 feet.

The relations of the Columbia terraces and the terrace materials to the underlying deposits are shown in Fig. 5, page 52.

Origin.—While a marine or estuarine origin for the terrace formations has been advocated, the question is still in dispute. The 0-25 foot terrace underlain by beds containing marine and brackish water-shells at Newport News, east of Norfolk, and in the Dismal Swamp area, is indisputably marine or estuarine.

^aThe writer believes that the Talbot formation in Virginia, as described by Shattuck, comprises two formations: in other words, the Chowan and Pamlico formations of North Carolina extend into Virginia.

WATER SUPPLIES

The coarser beds of the several Columbia formations are important reservoirs of water in Tidewater Virginia, and are tapped by thousands of dug or driven wells. As the sands and gravels often rest on relatively impervious clayey beds of Miocene, Eocene, or Cretaceous age, and are exposed along scarps or in stream gullies, they are the source of countless springs. On the high terraces the ground water is mostly soft and of low mineral content. On the lower area and especially near tidewater it differs greatly; in most places it is limpid and soft and excellent for general use; here and there so mineralized as to be unfit for many purposes.

Undifferentiated Columbia Beds

Extent and character.—Beds of mud, sand, clay, and gravel underlie the lowest Columbia terrace, or the terrace now in process of formation, at places in the eastern part of Norfolk, Elizabeth City, Gloucester, Mathews and Princess Anne counties, and the whole Eastern Shore. The chief objections to including these beds in the Talbot formation are that their indicated thickness would make this formation much thicker than any of the older Columbia formations, and that there is nothing to show that all the beds accumulated while the Talbot terrace was forming. Some may antedate the Talbot terracing; some may even be of Pliocene age. In the localities mentioned the beds rest on Chesapeake sands and clays. As they do not outcrop but lie below tide-level they can be differentiated from the Chesapeake beds below and the Recent or Columbia beds above only by the study of well records and samples of drillings. As few samples have been saved the age remains in doubt.

These undifferentiated beds comprise soft, dark bluish or greenish and bluish-gray sands with rounded and sharply angular grains, and coarse gravel. Some of the beds contain many marine shells, some contain cypress stumps or logs.

The sands in which the shells lie, sparsely scattered or in distinct layers, are medium fine, and, when dry, light gray in color; when wet, dark bluish or greenish. They apparently form discontinuous bands or lenses of varying thickness, no single sand bed having been traced far. The sands are for the most part soft, and offer little resistance to the drill, but locally contain indurated streaks usually only a few inches thick that the drillers term rocks. The beds are separated by dark clays of bluish or greenish tinge, that vary in texture from tough and firm clay to soft mud in which the drill of a light jet rig will sink five or six feet in as many minutes.

The soft clays, those most frequently found, are described by drillers as "blue mud" or "blue marsh mud." The shell beds, logs and stumps found in these beds on the Eastern Shore all lie considerably below tide-level. The following list of localities and depths to shell beds nearest surface in Accomac and Northampton counties is given for its geologic interest:

List of localities and depths to shell beds nearest surface in Accomac County.

	<i>Feet</i>		<i>Feet</i>
Accomac	50	Hunting Creek	90
Belinda	80	Mearsville	117
Bloxom	83	Mears Wharf	75
Boggs	104	Mappsville	70
Cashville	100	Mesongo Creek	115
Chesconnessex	100	Mt. Prosperity, near Onancock.....	60
Craddocksville	140	New Church	120
Hallwood	110	Pungoteague	110
Harborton	126		

Northampton County: Charlton 63 feet, Upshur Neck 128 feet; throughout Northampton County generally, 60 to 90 feet.

A well near Onancock, sunk 110 feet, is reported by the driller to have struck a bed of "beach sand" containing small shells at 65 feet and to have been bottomed in shell-rock containing "oyster" and "clam" shells. "Pieces of bark and knots of wood" were reported between 60 and 100 feet.

Another driller, F. A. Merrill, of Onancock, reports striking in a well on Grapeland farm, on Occahonnock Creek, three quarters of a mile from Wardstown Post-office, a "stump" 70 feet below surface or 60 feet below tide-level. A well at the house of Tully Scott on Masitank Creek, three quarters of a mile west of Cashville, according to the owner, went through "pieces of wood" at 64 to 68 feet.

WATER SUPPLIES

On the Eastern Shore many flowing wells draw on these deep-lying Columbia sands. The heads are low and seem to be largely determined by local topography. Thus there are few flows along the bay shore near Saxis, Belinda, and Marsh Market in Accomac County where the Talbot terrace slopes gradually to the expanses of salt marsh that border the tidal inlets; the ground, as well drillers say, is "too low." But there are many flowing wells on the bay shore farther south, where, as about Onancock and Harborton, a terrace plain 15 to 20 feet high, often overlooks open water. Again there are more flowing wells in Accomac than in North-

ampton County where the general elevation of the surface is less than to the north.

It is not possible that the supplies of these Eastern Shore wells could have come from across the bay; the beds under the bay contain salt water at too great a depth to permit that. They are fed from ground water that is supplied by the rain and snow that fall on the Eastern Shore. The underground circulation is southward and from the higher land along the axis of the peninsula toward the bay and the ocean. The heads of the water in particular wells or groups of wells are closely related to the height above sea-level of the water table in the vicinity of the wells. Since the water beds lie comparatively near surface, are overlain by muds or soft clays and extend under tidal inlets, the flowing wells of the Eastern Shore all show tidal changes, but the lag is less than that of the deeper wells of the western shore.

No flowing wells that evidently draw on these sands have been reported in Mathews, Norfolk, and Princess Anne counties.

As the deep Columbia beds comprise both clean sands and swamp mucks the contained waters vary greatly. Some of the sands yield excellent water—clear, soft, and low in mineral content, while other beds yield waters that are highly colored, hard, contain iron and have a decided odor of sulphuretted hydrogen.

SUMMARY OF GEOLOGIC FORMATIONS AND THEIR WATER SUPPLIES.

The geologic relations of the various Coastal Plain formations, their constituent materials, and their importance as water-bearers are shown in the following table:

TABLE 1.—*Geologic relations and water supplies of Virginia Coastal Plain formations.*

System	Series	Group	Formation	Materials	
Quaternary	Recent			Marsh and swamp muck, river silts and sands, beach and dune sands.....	(1)
	Pleistocene	Columbia	Talbot	Sands and gravels, clays and loams, less brightly colored than those of older terraces, old cypress swamps and beds of marine shells; 0-40 feet.....	(2)
			Wicomico	Cross-bedded sands; cobble beds and ice-borne boulders toward "fall-line"; clays and loams often bright-colored, some plant remains; thickness 0-40 feet.....	(3)
			Sunderland	Cross-bedded sands; cobbles and boulders; bright-colored loams; thickness 0-50 feet.....	(4)
Tertiary	Pliocene (?)		Lafayette	Cross-bedded sands, locally indurated, cobbles, and small boulders; bright-colored loams and clays; thickness 0 to 50 feet.....	(5)
			Yorktown	Gray sands; beds of marine shells, locally indurated; thickness 0-150 feet.....	(6)
	Miocene	Chesapeake	St. Mary's	Gray bluish or greenish sands and sandy clays and shell marls, weathering to bright hues; thickness 0 to 250 feet.....	(7)
			Choptank (?)	Gray bluish and greenish sands, locally indurated, sandy clays and shell marls, not recognized in Virginia.....	(8)
			Calvert	Gray bluish and greenish sands, locally indurated, sandy clays and shell marls, thick beds of diatomaceous earth, weathers to bright hues; thickness 0-300 feet.....	(9)
			Nanjemoy	Gray and greenish sands, greensand marls, locally indurated, dark clays, shell beds, all weathering to bright hues; thickness 0-125 feet.....	(10)
	Eocene	Pamunkey	Aquia	Gray and greenish sands, greensand marls locally indurated, dark clays, shell beds, all weathering to bright hues; thickness in outcrops 0-100 feet.....	(11)
	Upper Cretaceous			Does not outcrop in Virginia, comprises, under cover, greensands, gray micaceous sands and dark clays; thickness uncertain, over 500 feet.....	(12)
	Lower Cretaceous	Potomac	Patapsco	Bright-colored, evenly bedded clays, dark clays, arkosic sands, plant remains; thickness in outcrops 0 to 150 feet.....	(13)
			Patuxent	Cross-bedded arkosic sands with pebbles and cobbles, in places sandstone, conglomerate and shale, clay beds and lenses, plant remains; thickness in outcrops 0 to 250 feet.....	(14)

WATER SUPPLIES

-
- (1) Not important.
 - (2) Coarser beds supply ground water to springs and shallow wells; contain artesian water on Eastern Shore.
 - (3) Coarser beds supply springs and shallow wells.
 - (4) Coarser beds supply springs and shallow wells.
 - (5) Coarser beds supply springs and shallow wells.
 - (6) Ground water to springs and shallow wells, artesian water to a few wells.
 - (7) Ground water to springs and shallow wells, artesian water to many wells.
 - (8) May supply artesian water to a few wells.
 - (9) Ground water to springs and shallow wells, artesian water to many wells.
 - (10) Ground water to springs and shallow wells, artesian water to many wells.
 - (11) Ground water to springs and shallow wells north of Pamunkey River; artesian water to some wells.
 - (12) Artesian water of varying quality to a few deep wells near Chesapeake Bay.
 - (13) Ground water to springs and shallow wells, artesian water of varying quality to a few deep wells.
 - (14) Ground water to springs and shallow wells, artesian water of varying quality to a few wells near the "fall-line," and near Chesapeake Bay.

UNDERGROUND WATERS

ORIGIN, OCCURRENCE, AND DISTRIBUTION.

General statement.—Of the moisture that falls on the land in the form of rain and snow, part returns directly to the air by evaporation, part flows directly away by streams, and part enters the soil. The total precipitation on any region is distributed variously among these destinations, the exact amount that goes to any one being determined by factors which interact in an extremely complex manner.

Evaporation.—The proportion of rainfall that returns to the air by evaporation from the leaves of plants, before or after reaching the ground, or from the surface of the ground itself, varies greatly under different conditions. The temperature, the wind velocity, the character of the vegetation, the nature of the soil, all affect it. Evaporation is less in a cool climate with light winds than in a hot climate where fresh winds prevail. It is less from sandy than from clayey soils. It is less from fields than from forests. Tidewater Virginia has hot summers with liberal precipitation; on the other hand the wind velocity is low. Estimated on the basis of measurements at Washington, D. C., and including the water returned to the air by plants, evaporation in the Virginia Coastal Plain amounts to more than 50 per cent of the rainfall.

Run-off.—That portion of the rainfall that the streams carry away from a given district is the run-off. It includes the over-surface flow and the water from seeps and springs; it is determined by measuring the discharge of the streams, and is expressed either in inches, like rainfall, or as a percentage of the rainfall. The chief factors controlling run-off are vegetation and temperature. This is shown by Hoyt^a who finds that while the winter run-off in Vermont is 92 per cent of the rainfall and in Virginia is 63 per cent, the summer run-off is practically the same in the two states. No determination of annual run-off in the Virginia Coastal Plain has been made but it is probably less than in the Piedmont counties of the State, where it is 40 per cent of the rainfall.

Controlling factors in soil absorption.—The chief factors regulating the entrance of water into the ground are the slope of the surface, the rate of

^aHoyt, J. C., Comparison between rainfall and run-off in the northeastern United States. Trans. Amer. Soc. Civ. Eng., vol. 59, pp. 431-520.

precipitation, the air temperature, and the texture of the soil. On steep hillsides much rain water runs off before the soil can take it up; similarly, if the rain falls in a heavy shower less of it enters the soil than if it falls more slowly, because every soil has a certain rate of absorption, and if this be exceeded the excess water runs off. A high temperature decreases the surface tension of water so that water passes more readily through the soil pores. Sands have much larger pore spaces than clays, hence sandy soils take up water more rapidly than clayey soils.

In the Virginia Coastal Plain the conditions favorable to the absorption of moisture reach a maximum on flat expanses of terraces with sandy soils during gentle rains in warm weather.

Storage capacity of soils.—The capacity of a soil to absorb water is a measure of its porosity. In sands, the evenness of size of the grains and their roundness of outline determine the proportion of voids, because if the grains are round the total amount of open space is independent of the diameter of the grains. A clean, evenly sized sand with well-rounded grains will absorb water equal to 40 per cent of its bulk; a cubic foot of such sand will absorb about 10 quarts. Sharp sands that pack closely and sands with grains of various sizes absorb less. On the other hand, loams have proportionally more pore space and greater absorption capacity. Some determinations made by King^a showed that the percentage of pore space in clayey loams was about 44.5 per cent, and in sandy soils 30 to 35 per cent. Because of the great predominance of sands and sandy loams in the Virginia Coastal Plain, as shown in the table on page 29, it is probably safe to assume that the average absorption capacity of the soils is about 35 per cent.

SOILS AND SOIL SOLUTIONS.

Soils.—The soils of the Coastal Plain are derived almost wholly from unconsolidated beds of gravel, sand and clay, which in turn represent the washed-over debris of pre-existing unconsolidated beds, or the material worn from the hard rocks of the Piedmont Plateau. Since the Lafayette and Columbia formations lie blanket-like upon the older beds, and the latter are practically not exposed except where the Lafayette or Columbia beds have been removed by erosion, as on scarps, valley slopes, or narrow stream divides, the older beds are of less importance in the formation of soils. On the other hand the more or less weathered surfaces of the several Columbia formations form the cultivated soil of fully three-fourths of the Coastal Plain area.

^aKing, F. H., Nineteenth Ann. Report, U. S. Geol. Survey, pt. ii, 1897-98, pp. 213-214.

On the basis of origin, soils may be divided into two classes, residual and transported. A residual soil represents what is left from the decay of rocks, and rests where it formed. A transported soil is composed of material that has been moved by water, ice or wind. Residual soils characterize the Piedmont Plateau, transported soils the Coastal Plain. In the latter province the great agent of transportation has been water. There has been movement as dust but not enough to be of much importance in soil formation. There are accumulations of wind-moved sands, or dunes, back of some Chesapeake Bay or ocean beaches, notably at Cape Henry, but these are of little or no agricultural value. The water-moved rock particles were variously transported, some by streams and some by the waves and currents of the ocean or tidal inlets; they were deposited along river bottoms or on flood plains, in swamps or shallow bays, or in the ocean. Thus the finest of silts and the coarsest of gravel were laid down simultaneously in the formation of any one of the Columbia terraces. The terraces have been variously eroded since elevation above sea-level. Certain areas in all the terraces have been better drained than others, and the rate of decay of the soil particles has therefore not been the same. In consequence of original differences in mode of deposition and in material, and of subsequent differences in erosion and weathering, the soils vary decidedly within short distances and show very complex relationships.

Soils may be classified not only by origin but by topographic features, depth, suitability for certain purposes, and by physical characteristics. The latter are the most obvious guides. They comprise texture, as shown by the proportion of mineral particles of different sizes, structure (the manner of arrangement of the particles), and color. These physical properties form the basis of soil classification adopted by the U. S. Bureau of Soils, but other factors are considered. A soil class is based on texture, as shown by a mechanical analysis. Soils of different classes that are evidently related in origin, topographic position, and color, constitute a soil series. The structure and color determine with what series a soil can be correlated. The unit of a soil series is the soil type and the type is established by considering the physical properties and all other determinable factors that have to do with the relations of soils to crops.

In the Coastal Plain of Virginia the U. S. Bureau of Soils has mapped about 940,000 acres, and has discriminated 24 soil types in this acreage. The areas occupied by these types are shown in the following table compiled from figures published in 1909.^a The areas cover parts of Chesterfield and

^aWhitney, Milton, Soils of the United States, U. S. Bureau of Soils, Bull. 55. 1909, p. 233.

Hanover counties, all of Norfolk, Princess Anne and Warwick counties, and most of York and James City counties.

Area of soils surveyed in the Virginia Coastal Plain.

Name	Area of types in series	Total for series and types	Per cent. of total
	<i>Acres</i>	<i>Acres</i>	
Coastal beach		12,376	1.3
Chesterfield gravelly sandy loam.....		34,304	3.6
Chesterfield sandy loam.....		95,680	10.2
Elkton fine sandy loam.....		14,656	1.6
Leonardtown loam		43,584	4.7
Norfolk gravelly loam.....	1,344		
coarse sandy loam.....	4,288		
sand	11,200		
fine sand	20,864		
sandy loam	214,976		
fine sandy loam.....	230,272		
loam	23,872		
silt loam	5,952		
clay loam	1,856	514,624	54.8
Portsmouth sand	2,048		
sandy loam	50,048		
fine sandy loam.....	29,760		
silt loam	55,488		
clay loam	2,176	139,520	14.8
Swamp, tidal swamp and marsh.....		67,072	7.1
Wickham sand	4,416		
sandy loam	5,120		
loam	5,952		
clay loam	2,176	17,664	1.9
Total number of acres mapped.....		939,840	

The table brings out the relatively small extent of many of the soils, the predominance of two series, and the proportionally great extent of two types, the Norfolk sandy loam and the Norfolk fine sandy loam, which together occupy over 47 per cent of the area mapped. A survey of all the Virginia Coastal Plain might show soil types not as yet recognized there, and would change the present rank of some of the types, but would not alter the rank of the Norfolk series nor of its two predominating types—chiefly because these types occupy areas on both high and low terraces, whereas the topographic distribution of the other types as a rule is more restricted.

For a description of the soils named in the preceding table and their suitability for particular crops the reader is referred to the government bulletins from which the tables were compiled. The Norfolk soil series is

described as consisting of light-colored sandy soils underlain by yellow or orange sand or sandy subsoils, while the Portsmouth is characterized by dark gray to black surface soils underlain by yellow, gray or mottled yellow and gray subsoils.

As has been stated, the texture of a soil is determined by the proportion of the different sized mineral particles in it that are found by mechanical analysis. The U. S. Bureau of Soils recognizes seven grades, the limits of which are arbitrarily fixed. The texture of the Norfolk soil series is shown by the following table:

Textures of Norfolk soils.^a

Name	Fine gravel (2-1 mm.)	Coarse sand (1-0.5 mm.)	Medium sand (0.5-0.25 mm.)	Fine sand (0.25-0.1 mm.)	Very fine sand (0.1-0.05 mm.)	Silt (0.05-0.005 mm.)	Clay (.005 mm. or less).
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Norfolk gravelly loam....							
soil	5	13	12	17	18	25	9
subsoil	3	9	11	14	18	27	17
Norfolk coarse sandy loam							
soil	9	24	14	10	10	22	9
subsoil	11	38	20	11	4	9	5
Norfolk sand							
soil	3	15	22	38	10	8	4
subsoil	3	16	21	37	9	8	5
Norfolk fine sand.....							
soil	0	3	10	56	14	11	5
subsoil	0	2	9	53	16	14	5
Norfolk sandy loam.....							
soil	4	5	14	31	18	11	7
subsoil	4	12	10	22	12	12	26
Norfolk fine sandy loam...							
soil	1	3	5	38	24	22	8
subsoil	1	3	4	20	17	21	24
Norfolk loam							
soil	1	6	9	24	17	30	11
subsoil	1	6	9	20	15	29	19
Norfolk silt loam							
soil	1	3	4	10	14	54	12
subsoil	0	3	4	9	13	51	19
Norfolk clay loam.....							
soil	1	3	8	23	7	34	23
subsoil	0	4	6	18	7	32	33

^aU. S. Dept. Agriculture, Bureau of Soils, Soil Survey Field Book, 1906, pp. 47-54.

Soil solutions.—The solubility of the mineral compounds in the soil, under local conditions of rainfall, temperature and drainage, and the chemical reactions which take place in the underground circulation determine the quality of the ground water. The Coastal Plain soils, deep as well as surficial deposits being included under this term, comprise sands, loams, clays, shell beds, and beds full of glauconite. The sand grains are composed chiefly of silica, but in some formations many sand grains are made up of compounds of silica, alumina, iron, lime, potash, and soda. The ease with which these compounds are dissolved is determined not only by the solubility of the compounds but by the fineness of the soil particles, hence the quality of the ground water, that is, the kind and degree of its mineralization, varies decidedly from place to place.

In general the reason for the variations is easily recognized; lime carbonate is readily dissolved, hence shell beds contain limy, or "hard," water. Many iron compounds dissolve without difficulty, and iron-bearing solutions precipitate iron on exposure to air or by mingling with oxygen-bearing waters. Thus along the western edge of the Coastal Plain the loams that contain grains of iron sulphide worn from the Piedmont rocks are the source of "iron" and "alum" and "sulphur" springs and seeps; beds of bog-iron form where such waters accumulate on the surface, and iron crusts and bands grow along the underground water courses. Hydrogen sulphide, the compound which gives so many Coastal Plain waters a "swampy" or "marshy" odor, is derived not only from the dissolving of iron sulphide but from compounds found in the organic matter contained in many Coastal Plain beds; it may also come from reaction between sulphate of lime, a common constituent of soils, and other compounds.

Although as above indicated the mineralization of a particular water may be from causes easily recognized or self-evident, the quality of another water may be due to reactions that cannot be definitely traced, or to long-past events in the geologic history of the region. Instances of these differences are the high percentage of bicarbonate of soda in many Coastal Plain waters and the saltiness of others; in the one case we have to deal with a matter little understood, the selective interactions between certain mineral solutions underground; in the other with sea water which was originally in the beds or reached them after deposition.

GROUND WATER

Definition of ground water.—Of the water that enters the soil some is returned to the air through the capillary action of the soil particles and evaporation, some is absorbed by plant roots, stored in tissues, and ultimately returned by plant decay, or is given back to the air by transpiration from foliage; a little is taken up by the hydration or weathering of rock particles in the soil, and some reaches the ground water. By ground water is meant the water beneath the surface at any given point; its lateral extent and depth below surface are determined by several factors. Its lower limit may be at dense, impervious beds or there may be no sharp lower limit, the water filling crevices in rocks to an indefinite depth.

Water table.—The upper surface of the ground water is called the water table; it marks the water level in wells. Its depth below ground depends on topography, geology, and climate. In general the water table rises under hills and falls toward valleys. Under a level plain with soil of uniform texture, bounded by descents to lower ground, the convexity of the water table as a whole depends primarily on the texture of the soil and the difference in elevation between the plain and the lower ground. But the water table slope is modified by differences in soil texture, in the character and position of underlying rocks, in surface slope and in vegetation. It lies nearer the surface in fine textured soils than in coarse, and nearer under tilled fields than under forests. Where the water table cuts the surface of the slope there are seeps and springs; where confined hollows descend below the water table there are ponds. Under a flat expanse on a high terrace the water table may be at the surface, whereas near the scarp of that terrace it may be 50 feet below the surface of the ground.

Fluctuations of water table.—The water table rises after wet weather and falls after droughts, but these changes are not sudden. It takes a sensible period for the soil to absorb and transmit rainfall, so the water in wells may be low during a rainy period, in consequence of preceding drought, and may remain high long after rains have ceased. The seasonal differences in the height of the water table are the result of accumulative differences in the proportion of rainfall that reaches the ground, so that the period of lowest or highest ground water lags after the period of most or least rainfall, subject to superimposed modifications from evaporation and the growth of vegetation.

In Virginia the ground water is highest in the spring and lowest in the fall. These fluctuations are greater away from ravines and scarps than near them, because the water under a level stretch remote from any point of emergence moves very slowly and a rise in the water table of several feet increases the general slope toward the point of emergence but slightly, whereas near a scarp the water can run away so fast that the water table rises very little.

Besides being affected by the seasonal differences in rainfall, the water table is affected by other factors. Fluctuations in atmospheric pressure are among these. A rise of one inch shown by the barometer means an increase in air pressure equal to a foot of water. This load transmitted underground by wells can depress the well water by forcing it back into the sand and locally raising the water table. In the course of the field work for this report one instance of a dug well showing the effect of changes in air pressure was noted. This well, 26 feet deep, is near Potomac Mills, in Westmoreland County. The normal depth of the water in dry weather is about 2 feet. When the wind during such weather blows from the northwest, that is when the barometer is high, and the atmospheric pressure is heavier than the average, the level of the water in the well falls. With wind from the south-east, that is when atmospheric pressure is less, the water rises.

In very shallow wells changes in air temperature affect the surface tension of water. Cold increases the surface tension, hence if some of the ground water is near enough to surface (within a few feet) to feel the change, it rises into the partly saturated soil above the water table under the capillary attraction of the soil particles, thus lowering the level of the water in wells.

Change of level, due to natural or artificial causes, in nearby bodies of surface water—rivers, lakes, or the sea—may affect the water table decidedly. Where there is communication between such a body of water and nearby ground water, either through rock crevices or the pores between sand grains, a rise of the surface water raises the water table, either by direct transmission or by backing up the outward flowing ground water. Along Chesapeake Bay many shallow wells show tidal changes. These changes are not instantaneous since transmission through sands implies time, and along tidal bodies of water high water in a well occurs after high tide. The time difference or lag is governed by distance from shoreline and ease of communication below ground. It may amount to several hours.

Perched ground water.—Some accumulations of ground water are purely local. A sheet of clay may separate saturated sands from dry sands below,

resulting in what is known as perched ground water. Such a condition may be found at many places in Tidewater Virginia, and is especially noticeable after prolonged wet weather. Boring a hole through the clay draws off the perched water. In this way some ponds or swamps may be drained.

Circulation of ground water.—Two factors, gravity and capillarity, control the movement of underground water. Downward percolation, as the drainage of a soil after a rain, is largely due to gravity and takes place chiefly through the larger openings in the soil. On the other hand the water evaporated from a soil is supplied from below either by the capillary movement through the finer openings or by the creeping of thin films of water around the soil particles. Gravity and capillarity act together where the movement is downward or are opposed when the movement is upward. They combine to bring water to the surface on a slope.

The texture of the soil determines the relative efficiency of the two factors, because the soil openings are many times larger in coarse sands than in silts or clays. Practically, the water returned to the air by plants as well as that evaporated from the surface of the soil is supplied by capillary action, whereas the water of springs and wells is supplied by gravity. The relative importance of gravity and capillarity in the movement of ground water is nearly equal, the proportion of the rainfall that ultimately reaches the surface again under capillary action, being little less than the proportion of gravitational or drainage water returned by springs.

The movement of gravitational water toward some point of escape is modified by differences in soil texture, the position and character of the rocks below the soil, and the slope of the surface. By reason of the variety of factors the course of a drop of water toward some spring may be changed from a straight line many times.

In granites and other dense igneous rocks, circulation is by joint cracks of which there are usually three systems, one parallel to the surface, the other two steeply inclined. In stratified rocks, circulation is of two orders. In sandstones and conglomerates there may be both direct movement along the bedding through openings between constituent grains, and cross circulation through joint cracks. In shales, circulation is practically limited to joint cracks and bedding planes. In limestone, as the rock is readily dissolved, openings of considerable size may grow along bedding planes or cross fissures and may become large enough to take the entire volume of small rivers. The freedom of movement through sandstones and conglomerates is seldom comparable to that through sands and gravels, because of many original voids being closed by the cement that binds the grains and pebbles.

Rate of movement of underground water.—In fine sands with rounded grains the openings between the grains are of capillary size, and the frictional resistance to the movement of water is great; in sharp sands that pack closely the resistance is still greater. In coarse sands the voids are many times larger than in fine sands and the water can move with much more freedom. Ease of transmission through a soil thus depends on the size, shape and evenness of assortment of the soil particles, there being all gradations between coarse gravel and clay. A coarse sand transmits water 100 times as freely as a fine sand. A clay absorbs water but its transmission capacity is practically zero.

In discussing the capacity of soils to transmit water, Schlichter^a says:

If the particles of sand or gravel which make up the water-bearing medium are well rounded in form, the pores are somewhat triangular in cross section and the diameter of the individual pores is only one-fourth to one-seventh the diameter of the soil particles themselves. Thus if the individual grains of sand average one millimeter in diameter the pores through which the water must pass will average only one-fourth to one-seventh of a millimeter in diameter. If to a mass of nearly uniform sand particles larger particles be added the effect on the resistance to the flow of water will be one of two kinds, depending principally upon the ratio which the size of the particles added bears to the average size of grains in the original sand. If the particles added are only slightly larger than the original sand grain the effect is to increase the capacity of the sand to transmit water, and the more particles of this kind are added the greater will be the menace in the capacity of the sand to transmit water. If, however, larger particles are added the effect is the reverse. If particles seven to ten times the diameter of the original sand grains be added, each of the new particles tends to block the passage of the water. Thus, for example, a large boulder placed in a mass of fine sand will tend to block the passage of the water. As more and more of the large particles are added to a mass of uniform sand, the rate of flow of water through it will be decreased until the amount of the large particles equals about 30 per cent. of the total mass. From this time on the adding of the large particles will increase the capacity of the whole to transmit water until, if a very large quantity of the large particles be added, so that the original mass of fine particles becomes relatively negligible, the capacity to transmit will approach that of the mass of the large particles alone. These facts have an important bearing upon the capacity of gravels to furnish water to wells or to transmit water in the underflow of a river. The presence of large particles is not necessarily to be interpreted as indicating a high transmission capacity of the material, for this is indicated only when the large particles constitute a large fractional per cent of the total mass, as would be the case where the large particles equal 40 or 50 per cent of the whole.

The rate at which water moves underground is controlled by the resistance of the soil openings and by the slope or difference in height between two given points in its course. Through such mixtures of sand, gravel and boulders in nearly flat beds as lie in the terraces of the Virginia Coastal Plain, the rate is to be measured by feet a day rather than by miles a day, as in a surface stream. On the south shore of Long Island are Coastal Plain

^aSchlichter, C. S., Field measurements of the rate of movement of underground waters, U. S. Geol. Survey, Water Supply Paper No. 140, 1905, p. 10.

beds resembling in texture and inclination some of those underlying terraces in Virginia. Velocities have been measured there that range from 15 inches to 12 feet a day.^a

Underground lakes and rivers.—The belief held by many persons that underground waters in places outside of limestone regions lie in lakes or move as rivers, has little foundation in fact. The lakes and streams reported by well drillers are merely beds of saturated sand. The rivers described with great particularity by some water finders often are pure fiction, the stated course of an underground river having no relation whatever to the geology of the district.

Ground water temperature.—Soils absorb and radiate heat readily but transmit it slowly, so that daily temperature fluctuations are felt only a very few feet underground; even the changes from summer to winter become imperceptible at less than 100 feet, and the unvarying temperature there corresponds very closely to that of the mean annual temperature of the particular locality. Several factors combine to determine the distance below surface of this zone of unvarying temperature. In Tidewater Virginia it apparently lies at about 60 feet. Thus the temperature of shallow wells or springs varies seasonably, that of deep wells is constant. At depths of 20 to 40 feet, depths equal to those of the average dug well in the Tidewater region, the cumulative results of the winter's cold and the summer's warmth are minimum temperature in the spring and maximum temperature in the fall, but the difference between maximum and minimum is slight. In shallow, open wells the temperature of the water may be modified by heat taken from or given to the air, and changed decidedly by the entrance of water from near the surface after heavy rains, but allowing for these contingencies, there is no ground for the belief of many a well-owner that the water from his well is cold in summer and warm in winter; a thermometer will show him his error.

Chemical composition of ground water.—Rain that falls at the end of a shower is practically pure water. In passing through the soil the rain-water takes up carbon dioxide gas and also various salts. It attacks and slowly breaks down the resistant particles of the hardest rocks, reduces dense granite to grains of quartz and particles of clay, and completely dissolves beds of shells.

The chemical composition of the ground water at any point is determined by the rainfall, the drainage, the climate, and the composition of the

^aSchlichter, C. S., Op. cit. p. 67.

soil. Where precipitation is as abundant as in Tidewater Virginia and underground circulation is active, the soil at a certain point may be leached of easily soluble compounds in a time geologically brief; the ground water will thereafter have little solid matter in solution and will be soft and limpid. On the other hand, if the circulation is difficult the leaching will be less, and the mineralization of the water will persist for a longer period.

The soils of the higher terraces of the Coastal Plain of Virginia usually contain near scarps waters of extremely low mineral content; on the lower terraces the waters in places carry considerable iron or lime; on the lowest terrace, near the bay, where broad expanses of ground are covered by salt water during high spring tides, the ground water in places is distinctly brackish.

Few complete analyses of waters from dug wells are available, and the field assays presented in table 7 do not show the wide variety in quality of the waters. The analyses of spring waters (table 7) show the low mineralization of the waters from the sands of the high terraces.

Normal chlorine.—Chlorine, a constituent of common salt, is found in all surface and underground waters. It is derived from the sea as salt spray borne inland with dust particles by the wind and precipitated in rains, from the soil minerals, and from organic wastes. Hence the chlorine content of surface waters, other conditions not being considered, is greatest near the seashore and diminishes inland. The spring waters in table 7 show as a rule this chlorine decrease. In a given region the proportion of chlorine in the surface waters derived from soil minerals and from the sea is called the normal chlorine content of the waters. Any increase above the normal represents drainage from habitations, since the density of population on a given area has a direct bearing on the proportion of chlorine contained in the water flowing from that area. Hence, chlorine above normal in a surface water is taken as evidence that the water is or has been polluted.

Owing to variations in freedom of circulation and the composition of the soil, the normal chlorine content of the underground waters of a given region varies within wide limits, and a chlorine content above the normal of the surface waters does not necessarily denote pollution. A notable chlorine content in the waters from springs and shallow wells on high ground may indicate that the waters have been polluted, but many shallow wells near seashore tap waters that are normally brackish. High chlorine in the waters from a deep-drilled well is not necessarily evidence of pollution. In the water from a pumped well it may or may not be suspicious. Increase of chlorine in wells near the sea is not uncommon under heavy pumping.

Pollution of ground water.—Decaying organic matter carried in solution from the surface to the ground-water zone may make the water of wells or springs in the vicinity highly colored and offensive. Such discolored, ill-smelling water is rightfully viewed with suspicion, but a water that is clear, colorless or odorless may be much more dangerous. The menace to health is not the organic compounds in the water, but the microscopically small bacteria that cause specific diseases. These pathogenic germs may or may not be found in clear, refreshing spring waters having a local reputation for healthfulness or for curative properties.

A sanitary analysis of a ground water shows the proportion of compounds presumably of organic origin—nitrates, nitrites, and ammonia—and the proportion of chlorine. The proportion of organic compounds and of chlorine is taken to indicate the probable sanitary quality of the water. The value of such an analysis is disputed by many chemists.^a In Tidewater Virginia the almost universal use of wood-curbing in dug wells, the practice of dosing such wells with lime and salt after cleaning, and the large variations in chlorine content of the ground water at places on the shores of inlets, combine to make the value of a sanitary analysis even more doubtful than for surface waters unless the chemist knows the local conditions. A bacterial examination of a suspicious water may be decisive, but in most cases no examination or analysis of a water is necessary to show its doubtful purity. A glance at the well surroundings, the nearby privy, pig-pen or slop-hole, or the leaky curbing that permits any kind of filth to be washed in at every rain, will suffice to show why the well water is to be regarded with suspicion.

Areal extent of pollution.—In sedimentary deposits like those of the Virginia Coastal Plain, the decaying organic matter and the disease-spreading bacteria that reach the ground water are carried along its upper surface toward the nearest point of escape. The distance they may travel before they are destroyed by filtration and oxidation depends on the rate of movement of the water table and the fineness of the sands. Some recent experiments in Germany^b showed that heavy pumping could make bacteria from a polluted well 177 feet deep pass through 69 feet of sand and gravel (porosity 32 per cent) to an unpolluted well of equal depth in nine days; whereas if the bacteria were forced into the soil above ground water-level no pollution could be detected after prolonged pumping.

^aLeighton, M. O., The futility of a sanitary water analysis as a test of potability; Biological studies by the pupils of Wm. Thompson Sedgwick, Boston, 1906, pp. 36-53.

^bExperiments on the passage of bacteria through soil. Engineering Record, 1909, Nov. 4, vol. 60.

Where, as on many terraces of the Coastal Plain, coarse sand and gravel or shell marls underlie a few feet of surface loam, and the water moves with comparative freedom toward springs that flow from the terraces, conditions are particularly favorable to the spread of pollution underground. Any shallow well or any spring in the village may come under suspicion. Where waters from a possible source of pollution must pass through 10 feet or more of loam and sand to reach the ground-water zone the danger is lessened, but in general the radius of safety between well and source of pollution is not less than 100 feet. A dug well and a vault privy within the limits of the average 25-foot building lot favor a quick transfer of water from the well to the house and back to the well, but a more unsanitary arrangement can hardly be devised.

EMERGENCE OF GROUND WATER.

Seeps.—A large proportion of the ground water is returned to the surface or escapes below water level by seepage. Seeps make wet and boggy spots on slopes or at the base of scarps, and supply imperceptibly much ground water to bodies of surface water. Seeps differ from springs in size and localization of flow. Springs mark the escape of ground water moving in a definite passage through the open-textured portions of a porous bed or along crevices and solution passages in hard rocks. In other words, a spring is seepage water emerging in sufficient volume at one point to form a rill. No sharp dividing line separates seeps and springs; the gradation in volume and localization of flow is gradual. Many so-called springs in Tidewater Virginia are basins or shallow wells fed by seeps.

Springs.—Speaking of the tidewater country in general, Hugh Jones,^a an Englishman who visited Virginia early in the eighteenth century, said: "good springs abound everywhere almost." This statement holds true. Because of the liberal rainfall, the bedding of the Lafayette and Columbia sands, the manner in which pervious overlies less pervious deposits, and the many places at which the water table is exposed on bluffs and slopes or in gullies, springs of excellent water abound in most of the Coastal Plain counties. They are most numerous in the counties near the "fall-line." There are few where the surface is low and little eroded, as in Norfolk, Princess Anne, Mathews, Accomac and Northampton counties.

Because of its composition, extent, position, and great dissection, the Sunderland formation is the source of a majority of the springs.

^aJones, Hugh, *The present state of Virginia*, London, 1724; reprint, New York, 1865, p. 57.

TYPES OF COASTAL PLAIN SPRINGS.

Few of the Coastal Plain springs gush from rock crevices like the springs of the Piedmont region, or issue as giant flows from large cavities, like the springs of the limestone regions of the Great Valley. Instead the waters gently flow from the sands along terrace scarps or in ravines, and the volumes are small. In places where hollows in the surface of an impervious stratum, a bed of clay, a band of iron crusts, collect the water from a considerable area are springs of larger size. In places also springs of good size flow from open-textured beds of shell marl. Three types of springs are distinguishable. They may be termed normal, perched, and artesian or boiling springs, and their characteristics are shown in Fig. 3.

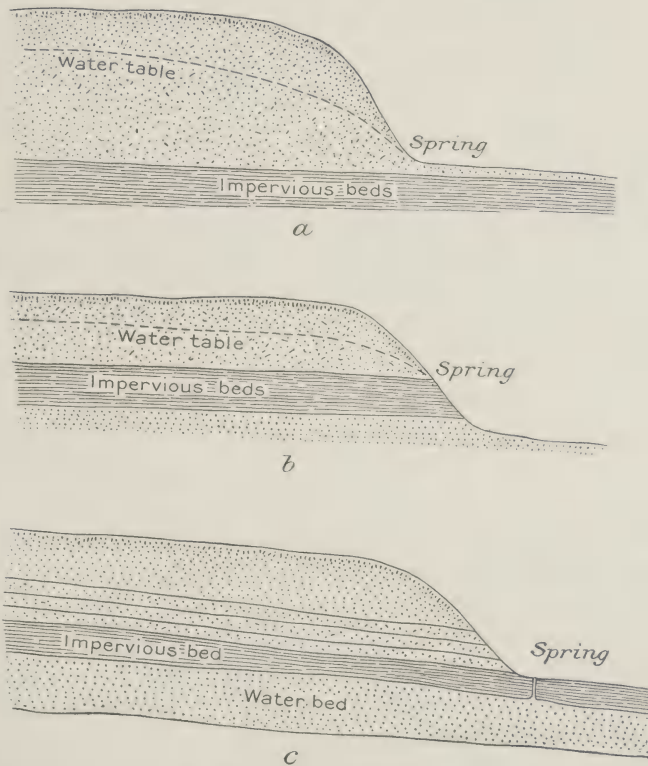


Fig. 3.—Diagrams illustrating types of Coastal Plain springs. (a) Normal spring. (b) Perched spring. (c) Artesian spring.

Normal springs.—Springs of the normal type are those that issue where the water table is exposed at ground-level. They are found in hollows on terraces along the bases of scarps, and on low terraces. Hence they are common to all parts of the Coastal Plain and flow from all the formations exposed. Many are of shallow source and go dry every year.

Perched springs.—This name has been proposed by Matson^a for springs from perched ground-water, those that issue from above some impervious layer exposed in a stream gully or terrace scarp. The point of emergence may be 100 feet or more above the foot of the bluff, or the point at which the top of the main ground water supplies springs of the normal type. Perched springs are characteristic of that part of the Virginia Coastal Plain having topography of the western shore type—interstream divides sharply cut by V-shaped valleys of creeks, high scarps facing rivers—this area lying between Potomac River and the divide separating the Chesapeake from the Chowan drainage. Thousands of them issue from the base of the Columbia formations above sandy clays of the Chesapeake and Pamunkey groups.

Artesian springs.—While the waters usually seep or flow from a slope, the face of a bluff or the side of a gully, in places there are springs that are slightly artesian, the waters rising with force enough to lift sand grains in the spring basin. Such are known as boiling springs. As a rule the impervious layer from under which the waters rise is less than 10 feet below the spring basin and at some springs is covered only by a thin wash of sand. In places the source is deeper.

SOURCES OF SPRING WATERS

In general the springs are fed by the rainfall on the particular terrace from under which they flow. As the terraces are cut up by stream valleys and the ground water takes the easiest course to its point of escape, in the majority of cases the water does not travel more than a mile or two underground, and in many places springs of some size flow from a narrow remnant of a Columbia terrace capping a divide, where the gathering area is less than a quarter of a mile wide.

The temperature of the spring waters shows that the springs are fed by the ground water of the terrace rather than from deep sources. Most "cold" springs have a temperature of about 58 to 60 degrees, or the mean annual temperature of the region. These "cold" springs flow from beds buried 50

^aMatson, G. C., Water Resources of the Blue-grass Region, Kentucky, Water Supply Paper, U. S. Geol. Survey, No. 223, 1909, p. 40.

feet or more. Springs which show higher temperatures than the annual mean do not have this temperature the year round. The water gets warmer in summer because of the shallow cover of the source. No spring in Tidewater Virginia, so far as known, has throughout the year a temperature above normal, as have the deep flowing wells, and evidently no spring freely rises from a depth of several hundred feet. Those that are coldest in the fall have the deepest source, and this source is not deep enough to show the increase of temperature due to depth.

PERMANENCE OF FLOW

Many springs in the Coastal Plain fail in every dry summer. Many yield less water after several months of drought, and many show slight difference in volume. These differences represent differences in the magnitude of the fluctuations of the water table.

Near the edges of high terraces wells go deep for water, and the height of the water in the wells changes but little during the year; springs flowing from the scarps of these terraces have much more uniform flow than those in hollows on terraces away from scarps, where wells are shallow and are full in the spring and dry in the fall. Still there are springs having immediate shallow sources that flow the year through with little reported change in volume. Some such springs evidently are supplied by water that comes through a confined channel so small in proportion to its length that fluctuations of ground water level are minimized. Springs flowing from crevices in granite in hollows of high terraces are of this class, other springs which show little change in volume though having apparently shallow covers are fed by the water that comes from under a terrace above the one that seems to supply them.

PURITY OF SUPPLY.

Pollution of spring sources.—As most of the Coastal Plain springs flow from sandy beds covered by loams, surface waters undergo filtration in reaching the ground-water zone and in traveling to the point of emergence. Hence as a rule the springs of the Coastal Plain, if properly developed, are not likely to be the source of disease. On the other hand, where cities or villages stand on terraces having a thin cover of loams and coarse sands below, the ground water is easily contaminated by leakage from cesspools or sewers, or the impurities washed into dug wells, and springs flowing from the scarps of such terraces may be altogether unsafe no matter how clear, sparkling and refreshing their waters are.

Quality of spring waters.—The quality of the spring waters varies widely. As a rule the waters from the Columbia sands of the higher terraces are soft, contain little iron, and are suited for all domestic purposes. Springs from the lower terraces show greater differences. Many “marl springs” that flow from shell-marl beds in the Pamunkey or Chesapeake group, yield hard water. Here and there, particularly along the western edge of the Coastal Plain, are small springs whose waters contain sulphates of iron and alumina.

The analyses in table 6 show the characteristic differences in mineralization of the springs flowing from sands, from granite, and from marl, and the modifications resulting from topographic position. The granite, and the sand and gravel springs of Alexandria and Chesterfield counties contain less than 100 parts per 1,000,000 of total solids, and many are extremely soft, some containing less than 1 part per 1,000,000 of calcium. They are also low in chlorine. Evidently the sources of mineralization of the granite and the slightly mineralized sand springs are approximately the same, being derived from well-leached or relatively insoluble soils. On the other hand, the marl springs and the springs in low terraces near Chesapeake Bay show as a rule more total solids, more lime, and more chlorine. The most heavily mineralized waters in the table are those from two marl springs, one in Surry County and one in Sussex County.

DEEP AND ARTESIAN WATERS.

Function of ground water.—The greater part of the ground water in Tidewater Virginia does not rest on a clearly defined impervious floor, but lies above more or less pervious rock or unconsolidated material and there is no sharp line of demarcation between the ground water and what may be called, for convenience, deep or artesian water. Where, as in the Piedmont province, there is a mantle of rotted rock and residual soil, or where, as in the Coastal Plain, there are blanket-like formations of unconsolidated material, it is often convenient to take the top of solid rock or of beds older than those lying at the surface as the base of the ground-water zone and to regard the surface material as constituting a great sponge, its function being to absorb and store precipitation and slowly feed ground water to crevices and porous beds in the underlying formations.

Deep circulation.—Circulation below, as in the ground-water zone, is determined chiefly by gravity, but although in a general way influenced by topography, it is closely controlled by geologic structure. The porosity of the beds, their dip, the size and extent of cracks or fissures, are more im-

portant than topographic differences. So while the ground water flows down a valley, the deep water may move in a direction at right angles to the valley's trend.

The deep circulation may extend to far greater depth at one place than at another. Thus, where porous beds are steeply inclined or the continuity of rock masses is broken by profound fissures, water may circulate thousands of feet below the surface. On the other hand, where thick flat beds of shale lie near the surface there may be little or no deep water, as in certain regions of Pennsylvania and adjacent states.

While primarily governed by gravity, deep circulation may be assisted by the increase of temperature with depth; the waters from the surface working downward reach higher and higher temperatures until, through some comparatively free way of ascent, they rise and emerge at the surface as thermal springs. Also, deep waters may become so charged with gases that they rise more strongly than by difference of level alone.

In the Coastal Plain of Virginia deep circulation is along gently inclined porous strata and neither gain in temperature nor gaseous content is an important factor in the movement of the water. Flow down hill is sufficient to account for the facts observed. Yet, while the water moves down the dip of the porous beds toward the sea, the course of a single drop may be anything but a straight line. The beds are not of uniform texture for long distances. Instead, the water-bearing sands form irregular partly connected or discontinuous lenses, here coarse, here fine, and a drop following the line of least resistance may move down, across or even up the general dip of the beds. The limiting depth of active circulation is unknown, but the high mineralization of the deep waters in the Norfolk region indicates that their circulation is feeble.

Temperatures of deep water.—The thermal gradient, or rate of increase of temperature with depth, varies from place to place being most rapid in regions of recent volcanic activity. Unless running freely through open passages, underground water has the temperature of the material in which it is found. Hence temperatures of a large number of wells of varying depth show the temperature of the line of no change, its distance below the surface, and the increase of temperature with depth beneath.

Some observations in Tidewater Virginia indicate that the mean temperature of the line of no change is 56° to 59° and that the line lies at least 50 feet below surface; its exact depth was not determined because of the difficulty of getting the temperature of the water in the relatively small number of wells 50 to 100 feet deep.

Temperatures of flowing wells measured at the surface are subject to error. In most of the older artesian wells in Tidewater Virginia casing goes only to some dense bed below the Columbia sands and gravels. In some areas, as at West Point, two or even three deep water beds have been penetrated, and the flows from all the sources mingle, so that the temperature at a certain well is not the temperature of any one flow. Again in rising through several hundred feet of pipe water loses heat. Hence of two wells side by side tapping the same water bed, the one poorly sunk or cased that yields a mere dribble will show a decidedly lower temperature than its freely-flowing neighbor; for the same reason the flow of a 6-inch well will show the temperature of the source more accurately than that of a 2-inch well.

Temperatures of a considerable number of flows were taken in the course of field work, as shown in table 6. These temperatures are subject to the possible errors above stated, the most trustworthy figures being those of the freest flows.

In the following table are grouped the depth and temperature of flow of a number of wells:

Temperatures of artesian flows in Virginia Coastal Plain.

Location	Depth	Flow	Temperature of flow	Probable mean ann. temp. of locality
	(Feet)	(gal. per min.)	(°F)	(°F)
Mount Holly	153	15	63	
Chain Ferry	172	10	62	
Warsaw	188	16	62.5	
Coan	188	16	62.5	
Tappahannock	256	5.5	62.5	56
Boulevard	266	52	63	57.5
Jamestown	270 (6-inch well)	40	65	56.5
Bayport	300	20	64	56.8
Jamestown	300 (3-inch well)	78	64	56.5
Freeport	330	2	63	
West Point	335	37	66	
Curtis Point	361	2	67	56.6
Leehall	400	2	65	56.4
Urbanna	476	25	68	56.8
Irrington	580		69	56.3
Lamberts Point	616	51	72	59
Selden	716	52	70	57

The indicated average gradient of 1° for each 40 feet increase in depth is probably a close approximation to the truth.

The above table subject to the errors indicated may be used for roughly checking the depth of a well. For instance, the water from the bottom of a

well 300 feet deep should have a temperature of about 64° F. This check however is of no value unless an accurate instrument is used. Many cheap thermometers are not correct within 2 degrees, and to use one of these is a waste of time.

Composition of deep water.—The substances in solution in the deep water at a given point necessarily bear some relation to the composition of the enclosing beds, to the depth below surface, and to the freedom of movement, but this relation is often extremely obscure. The chemical reactions that take place, under the conditions of circulation in solutions as dilute as most underground waters, are hardly comparable with the reactions observed in a chemical laboratory.

In Tidewater Virginia the mineralization of the deep waters increases toward the southeast. This change is not directly due to increase of depth, nor has it been shown to be due to changes in the composition of the enclosing beds. The rank of the controlling factors is discussed in the consideration of the artesian flows of the Norfolk-Newport News area. Defective circulation seems most important.

ARTESIAN WATERS

Definition of artesian.—The term artesian well has different meanings in different parts of the United States, being applied variously to all bored or drilled wells much deeper than the dug wells of the particular locality, to deep wells in which the waters rise, and to wells in which the waters rise and overflow. Even in Tidewater Virginia usage is not uniform. Both the deep drilled wells with water-level 100 feet below surface, at Richmond, and the much shallower flowing wells along river banks or the shores of Chesapeake Bay are called artesian. In this report the word artesian is used to designate the hydrostatic principle, the tendency of water to seek its level. Hence artesian waters are those which rise when the beds containing them are tapped. An artesian slope is a slope with artesian water below it, and an artesian well is one that taps artesian water. A well in which the water rises above ground-level is called a flowing well.

Artesian conditions.—Flat-lying ground water obviously cannot be artesian; the water in a well sunk to it will stand at the level of the water table. Difference of elevation is essential, the other conditions vary from place to place.^a

^aFor a discussion of all the factors involved, see Summary of the Controlling Factors of Artesian Flows, by M. L. Fuller, U. S. Geol. Survey, Bull. 319, 1908, 44 pp.

In Tidewater Virginia the governing conditions are these:

- (1) Sufficient rainfall.
- (2) Porous beds that receive rainfall directly or indirectly.
- (3) Differences of elevation.
- (4) Sufficient slope to the porous beds to carry them below less pervious beds.

Coastal Plain an artesian slope.—The Coastal Plain formations dip seaward. They contain water-filled open-textured beds overlain by relatively dense beds. The confined waters are artesian, and the Coastal Plain is an artesian slope. Some conditions causing artesian water are indicated in Fig. 4.



Fig. 4.—Diagram illustrating artesian conditions in the Coastal Plain Province of Virginia. (a) Well penetrating two artesian sands; strong flows because of sands pinching out or becoming clayey. (b) Well finding no water in beds penetrated by (a), but drawing on a water bed that does not outcrop. (c) Well to isolated sand bed, water under low head.

Source of artesian water.—To account for flowing wells some persons assume a great difference of elevation is necessary and say of the water gushing from a bore hole that it must “come from the mountains.” They do not realize that there is no difference in principle between water rising in a well to 10 feet above the water bed and water rising to surface, nor do they realize that the heads of the flowing wells are low in comparison with the elevation of hills not far distant. The water that gushes from a well in Tidewater Virginia either entered the artesian bed at its outcrop or was fed to it from overlying beds. In either case the water entered the ground within the Coastal Plain. Some topographic relations of the artesian flows are shown in Fig 5.

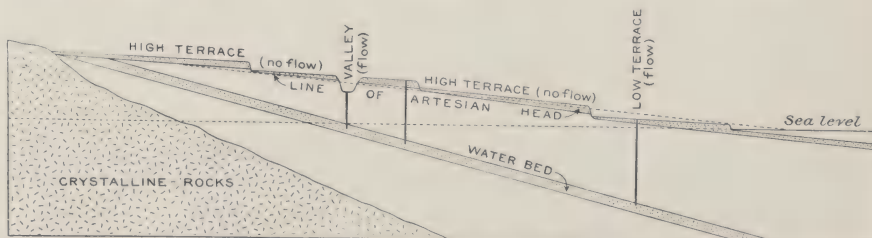


Fig. 5.—Diagram illustrating relations of head of artesian wells to topography in the Coastal Plain Province of Virginia.

Initial head.—As the Potomac, Rappahannock, Pamunkey, Mattaponi, and James rivers have cut valleys to the western edge of the Coastal Plain, the outcrops of beds or zones that carry artesian water to the east are exposed from tide-level almost to the tops of the interstream divides. Hence what may be called the initial head of the waters is not represented by the elevation of the porous beds at their edges on the divides nor by the height of the water table in deposits overlying the upper edges of the beds, for there is leakage toward the valleys.

Loss of head.—Ordinarily water never rises as high in a well as the level of the ground water supply of the artesian bed. This loss of pressure is due to the frictional resistance the water has met in passing through the sands, and to leakage in the journey to the well or down the dip of the beds beyond the well. Where water is confined under pressure in a widely-extending bed of uniform size sand grains through which the movement of water in any given direction is very slow, the flow to a well is along the bed from all directions at practically the same velocity, and the loss of head by frictional resistance during transmission from the distant source is small. Thus in that vast artesian reservoir of the Great Plains—the Dakota sandstone—the loss of head down the dip is only about 1 foot per mile. Water in beds of sand less evenly sized or less confined shows much greater loss of head, 100 feet per mile or even more.

In the Coastal Plain of Virginia are artesian sands in which the size, the angularity, the evenness of assortment, and the looseness of the component grains vary greatly, hence water circulates through them at various rates. On this account, and because of the uncertainty as to the probable initial head of the water found at any place, and because of errors in drilling and casing, it is difficult if not impossible with present records to determine the loss of head per mile of the water in a particular sand or connecting series of sands. In some places the more eastern wells show higher heads than do other wells to the west tapping the same formation at about the same horizon.

Ponded water.—Though the water that enters an artesian bed in the Coastal Plain deposits tends to move downward, that is seaward, toward some point of escape, ever getting deeper under cover, there are undoubtedly waters confined by sand beds pinching out or becoming clayey in all directions but one, and therefore practically stagnant. Such stagnant or ponded waters far below sea-level may be highly mineralized, because the sands in which they lie have not, since deposition in the sea ages ago, been thoroughly flushed by vigorous circulation, or because in depressions of the land the

beds up the dip were saturated with sea water which displaced the fresh water below.

FLUCTUATION OF LEVEL IN ARTESIAN WELLS

Some agencies that cause fluctuations in the level of the upper surface of the ground water, the water table, cause fluctuations of the water in artesian wells. The most effective in Tidewater Virginia are changes of level in bodies of water on the surface. Since there can be no free communication between the deep and the surface water, otherwise the deep waters would not be artesian, there can be no direct transmission of water, nor of pressure, through porous beds. The pressure is transmitted through the relatively impervious beds that confine the artesian water. A river flood, a high tide, a flooded swamp means increased load; this pressure is transmitted downward to the covered sands through the saturated but impervious clays, causing a slight plastic deformation, and the water in wells sunk to the sands rises. In flowing wells this rise is shown by increased yield.

There are along Chesapeake Bay and its tributary rivers hundreds of wells showing marked tidal changes, some flowing only at and just after high water. In fact it is probable that all the deep wells on the shores of Chesapeake Bay or its tributaries show tidal changes, though in some the rise and fall of water are very slight and are not detected.

A change in atmospheric pressure can affect deep wells as it affects shallow ones. If the well flows, increased pressure may be shown by diminished yield. Near Sealston, in King George County, John Curtis has a 2-inch drilled well, 250 feet deep, that normally yields about two-thirds of a gallon per minute, the water rising only a few inches above the surface. This well flows most strongly before an easterly storm (when atmospheric pressure is less than normal) and during one period of cold weather with northwest winds (high atmospheric pressure) it ceased flowing for two days.

QUALITY OF ARTESIAN WATERS.

The wells drilled to the known Potomac sands are either near the western edge of the Coastal Plain or far to the east, there being none in the intermediate areas. Hence it is impossible to trace the changes in mineralization of the Potomac waters under cover. Similarly, as Upper Cretaceous beds have been recognized only in deep borings near Chesapeake Bay, nothing definite is known regarding the quality of the water in Upper Cretaceous beds further west. It is certain, however, that the waters in both the Potomac (Lower Cretaceous) and Upper Cretaceous beds show a progressive

increase in mineralization toward the southeast, like the waters in the Pamunkey and Chesapeake sands. The increase in bicarbonates is the most noteworthy feature. Waters which near the outcrop of the beds may be either soft or hard, take up bicarbonates, and if originally hard become soft by losing much of the lime they contained. Such sodic bicarbonated waters are not peculiar to Virginia; they are found in other parts of the Coastal Plain, especially in South Carolina. But in Virginia they underlie the larger part of the Coastal Plain west of Chesapeake Bay, and are remarkable because they differ decidedly from the ground water from which they are derived, and because the change from the calcic bicarbonated (hard) ground water in the marl beds of the Chesapeake and Pamunkey groups to the sodic bicarbonated (soft) artesian waters, takes place during a relatively short underground journey. As a rule the artesian waters become more mineralized by taking up chlorine, bicarbonate, sulphate, and sodium radicles; that is, while there is a decided increase in the proportion of several acid radicles there is less increase in the basic radicles, except sodium.

At some places, as for instance, Hardings, Northumberland County, and Smithfield and Shoal Bay, Isle of Wight County, there are waters that are practically dilute solutions of sodium bicarbonate. Although chemists have reported high carbonate contents in the waters at several places, these waters may actually contain no carbonates, or little more than a trace. It is probable that at comparatively few places does the content of carbonates amount to over 30 parts per 1,000,000. The carbonate content reported in some analyses represents the chemist's opinion rather than the salts actually in solution.

Bicarbonated waters stimulate the growth of algæ. The difference in this respect between most ground waters and the soft artesian waters is striking. A heavy growth of "green moss" accumulates in troughs and about the mouths of flowing wells in many counties west of Chesapeake Bay.

Sodium bicarbonate waters have certain physiological effects and are not well adapted for all industrial purposes. Their healthfulness, their value in the treatment of disease, and their suitability for specific uses in the arts, are considered in another chapter.

ARTESIAN SANDS

Number.—It is extremely doubtful if there is a single water-bearing stratum in Tidewater Virginia that is of wide extent. The water beds are to be regarded as sands of varying porosity, laid down in interleaved lenticular deposits containing discontinuous streaks of hard rock. Thus while

the wells along any given stretch of river may reach the same artesian zone, the depths to the points from which freest flows come may vary irregularly.

The total number of the artesian sands is unknown. Few wells have been sunk deep enough to prove all of them in the formations above the top of the Potomac group, and the Potomac, under cover the thickest of the groups, contains more sands than all the overlying formations combined. Yet except for what is told by the records of the Fort Monroe and Norfolk City Water Works wells nothing is known of the Potomac sands under cover far from their outcrops.

Potomac sands.—The Patuxent formation contains sands that under cover are probably as irregularly bedded as in their outcrops. Hence at one place the Patuxent may contain several beds freely yielding water, and at another not far distant show but one or two and these of feeble yield. Still, except in Norfolk, Princess Anne, Elizabeth City, and Mathews counties, and the eastern end of Gloucester County, good water is to be expected from the lower Potomac formation along the entire western shore of Chesapeake Bay, the mineralization increasing, deep under cover, toward the southeast corner of the State. The best chance for liberal yield is near bed rock rather than some distance above. On the Eastern Shore the Potomac lies so far below surface that there is little hope of getting good water from its lower beds. The most important wells drawing on the Patuxent are at Alexandria.

The Patapsco formation, or upper part of the Potomac group, contains water-bearing sands, though toward its outcrop only a few artesian wells are known to draw on them. Of the eastward extent of the Patapsco, as of the Patuxent sands, little is known. The upper part of the 1,300 feet or so of Potomac strata found in the Norfolk area has been shown to contain a number of water beds, and it is probable that under the whole of Tidewater Virginia, the upper Potomac contains artesian water, though the quality of the water is variable, and in the southeast part of the State is poor. On the Eastern Shore there is a possibility of getting fair water from the upper beds of the Potomac near the Virginia-Maryland line, but there is little chance of good water from the Patapsco formation in Northampton County.

For a fuller discussion of the quality of the supplies obtainable from the deep-lying Potomac beds the reader is referred to the account of the deep wells of the Norfolk-Newport News area in another chapter.

Pamunkey sands.—Though they vary irregularly in thickness, the water beds of the Pamunkey have much more continuous layers than those of the

Potomac, and because they lie nearer the surface have been drawn on by a far greater number of wells. They have been developed along the Potomac, Rappahannock, and James rivers, and reached by a few wells near Chesapeake Bay.

Of the two Pamunkey formations the Aquia is more important as an artesian reservoir than the Nanjemoy. The former underlies a wider area, and has been more developed along the Potomac and Rappahannock rivers.

The Nanjemoy formation is, however, an important water-bearer and near its base contains sandy beds that have been tapped by many wells between Potomac and James rivers. Little is known of the extent of the Nanjemoy formation south of the James; apparently it thins or is cut out along a northwest-southeast line so that few, if any, of the many wells in Southampton County draw on it.

Chesapeake sands.—In Tidewater Virginia the number of artesian wells drawing on Chesapeake sands is greater than the combined number of those drawing on Pamunkey or Potomac beds. This is because the artesian beds of the Chesapeake, in much the greater part of the area, yield fair to liberal supplies of good quality. Hence the beds below the Chesapeake have been explored only near or beyond the western edge of the Chesapeake outcrops, or where the Chesapeake supplies have been unsatisfactory.

Most of the artesian wells on the western shore of Chesapeake Bay in the territory lying east of a line running from Pope Creek, on the Potomac River, through Piping Tree, on the Pamunkey River, to Claremont, on the James River, draw on Chesapeake sands.

Well records along the Potomac and the Rappahannock rivers show a number of Chesapeake sands. They are thin and of varying persistency. The most persistent are in the lower half of the group in the Choptank (?) and Calvert formations, especially the latter. Those near the top, in the St. Mary's and Yorktown, are more patchy. Along York and James rivers the sands yield water less freely than to the north, and toward the mouths of these rivers the Chesapeake contains few sands that give flows and these are neither continuous nor regular.

On the Eastern Shore irregularly distributed sands near the top of the Chesapeake group, possibly high in the Yorktown formation, contain artesian water that supplies a few flowing wells along inlets from the bay or the ocean. This water varies in quality but on the average is very different from the artesian supplies found in Chesapeake beds on the western shore of the bay.

Columbia sands.—Generally thin, and for the most part lying above tide level, the Columbia sands on the western shore of Chesapeake Bay contain artesian water but rarely. Here and there “boiling” springs show artesian conditions but no flowing wells drawing on Columbia sands have been reported. On the Eastern Shore the Columbia sands are thicker and local conditions favor the storage of water under pressure in beds 50 feet or so below surface, which are here classed as Columbia.

The relation of some of the artesian water beds in the Potomac, Upper Cretaceous, Pamunkey, and Chesapeake groups are shown by the sections given in Fig. 6.

Flowing well areas.—As very few flowing wells in Tidewater Virginia have heads that are more than 35 feet above sea level, and heads on the Eastern Shore are under 10 feet, the flowing well areas are limited to the low ground bordering the bay or the ocean, and to strips of country of varying width along river and creek valleys. In other words, the flowing wells are confined to the shores, or to the terrace slopes. Enough drilling has been done to establish the extent of several artesian horizons west of Chesapeake Bay. It is certain that water which will rise above tide level can be had along the principal rivers from a short distance east of the “fall-line” to their mouths. Waters which will rise 25 feet above tide can be had along Potomac River east of Matthias Point, along the Rappahannock from 15 miles east of Fredericksburg, along the Mattaponi below Beverly Run, along the Pamunkey below Enfield, along York River, and along the James below Wilcox Wharf. Wells of high head can also be had around the east end of the peninsula between Potomac and Rappahannock rivers. Between Rappahannock and James rivers, however, in Mathews and Elizabeth City counties, several deep wells did not get flows and the yield of others has been disappointingly small. East of Norfolk, in Norfolk and Princess Anne counties, flows can be had, but the prospects for potable water from the formations which give fine flows to the west and northwest is distinctly unpromising.

Water that will rise 20 feet above tide, and in places even higher, can be had along Blackwater River south of McClelland, along Nottoway River south of Lumberton and along its principal tributary Assamoosick Swamp south of Littleton, along Three Creek east of Arringdale, and along Meherrin River from 15 miles below Emporia. As there are no topographic maps that show the lowest terrace along all the rivers, it is impossible to state the total extent of the area on the west side of Chesapeake Bay in which flows can be had.

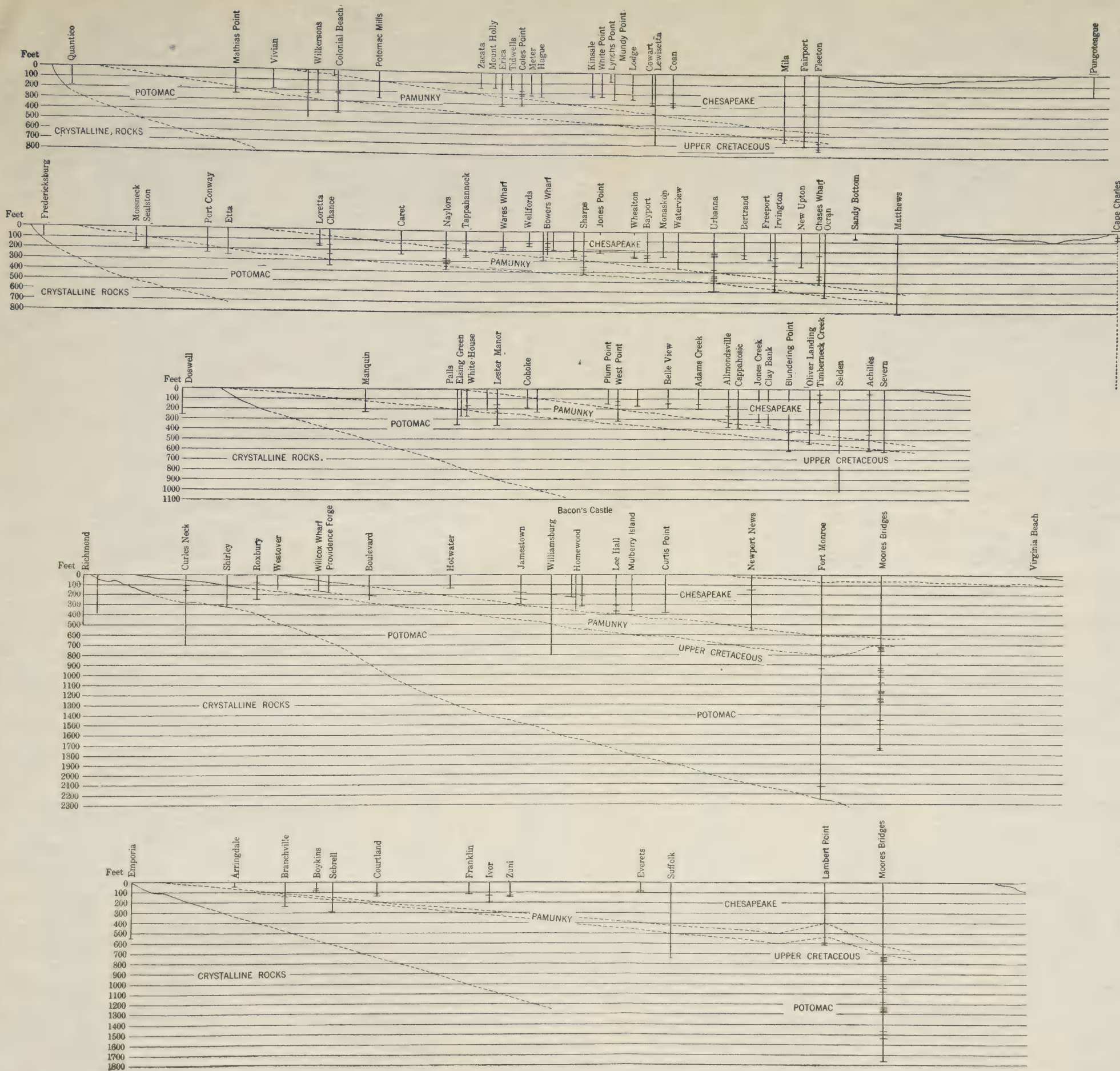


Fig. 6.—Sections across the Coastal Plain Province of Virginia, showing geologic relations of artesian sands and of wells drawing on them. Columbia formations not shown except in section from Richmond to Virginia Beach.

On the Eastern Shore, where the heads of the artesian waters are much lower, flows may be had along the shore in many places, as shown by the records in table 1. They can not be had at every place where the surface elevation is less than 5 feet, though it is probable that the flowing well areas will prove to be more extensive than the records indicate, particularly along the ocean side of the peninsula.

Some of the many flowing wells and the westward limits of flows from sands in the groups of formations are indicated in Plate I.

Conservation of artesian supplies.—The artesian supplies obtainable under the greater part of the region investigated are so abundant that their conservation and even their most advantageous development have received little attention. The situation at West Point and at Colonial Beach, where hundreds of wells no longer flow, depriving owners of advantages that in the aggregate have a large money value, shows that conservation can not be neglected. While such severe restrictions on the use of underground water as some states have imposed are not required, there is already need for local regulation. Waste is unnecessary and may work public injury. Where many wells have been driven those on low ground need not be allowed by unrestricted flow to diminish or cut off the flow of wells on higher ground. Neither is it right that the static head of the water in an underground reservoir should be lowered to the detriment of innocent parties by the insufficient casing of new wells or by the neglect of old wells. The casing of wells at wharves may be damaged by accident or corrosion, allowing a part or the whole of the flow to escape below tide level. It is obviously unjust to permit this where it means loss to other property owners, and where it can be prevented by the simple expedient of plugging the well. It is true that at both Colonial Beach and West Point there are undeveloped sands that can furnish plenty of water, and the depletion of all the sands is a remote contingency, but this does not alter the essential injustice of permitting the impairment of an important natural resource, and the depreciation of private property by carelessness and neglect, especially when preventive measures are simple and inexpensive. Sooner or later the fact that the interests of the public are superior to those of any individual will be so generally recognized that unnecessary waste will not be tolerated.

RECOVERY OF WATER

CISTERNS

The cistern is one of the oldest human devices for procuring a supply of drinking water, and it remains the most practicable source of supply in many localities. Cistern water is soft and is usually regarded as pure, hence cisterns are dug where ground waters are hard, irony or brackish, or are liable to pollution. In the Coastal Plain of Virginia there are some villages and many isolated dwellings that rely chiefly on cisterns. The sanitary quality of the water stored compares favorably with what is obtained by the ordinary type of dug well but is seldom as excellent as it is thought to be, since cisterns, like wells, may be polluted from below and from above. Some cisterns are not tight and impure ground water can find its way in when the level of the cistern water is below the water table. Many cisterns are not properly covered and back-yard dust and insects get in. The chief source of contamination, however, is from the roof. Dust, dead insects, and the droppings of birds fall on roofs and accumulate in eaves troughs to be washed into cisterns at the first shower. Where birds perch on buildings the danger of contamination is obvious, but even where such gross pollution is not apparent, danger may lurk. The small box filters of sand or charcoal, such as are often used, do little more than remove visible impurities; the bacteria that cause disease pass through. In fact, such filters, unless the contents are frequently renewed, may become breeding places for pathogenic germs.

Good cistern water is rain water properly collected and properly stored. Hence, cisterns should be tight, also they should be large, that only the best rainwater need be saved, that which falls at the end of showers when the air is free from dust and roofs and gutters are washed clean. There should be provision for diverting the water from the roof during the first part of a shower, and if filters are used they should be large so that the water will have to go through not less than 3 feet of fine sand before it reaches the storage chamber. In addition the cistern should be tightly covered and provided with a good pump. To allow farm laborers to bail water from a cistern is to invite infection.

SPRINGS AND SEEPS

Probably 90 per cent of all the springs in the Coastal Plain area issue as small flows from sandy beds in the Columbia formations, or from sands

and marls in the Chesapeake. Some of the marl springs are of considerable volume although none are known that approach in size the large limestone springs of the western part of the State. In former days it was customary throughout Tidewater Virginia to supply the manor houses, when possible, with spring water—in fact the location of many houses was determined by the finding of a suitable spring. A wood or masonry basin and a wooden shelter as a spring house were the usual improvements, and buckets the means of conveyance, though sometimes a hand-power pump at the spring forced water to a tank in the house. It is no longer easy for the average household to obtain water in the old way, and the use of springs for household supply has greatly diminished.

Improvement of springs.—The improvements required at springs are few. A basin of tile or concrete, or even of wood, with a spout and a tight cover, are the chief requisites. The common arrangement of an open basin from which water is dipped, and steps leading down to the basin, facilitates pollution.

Use of rams.—To have a supply of spring water in a dwelling above the spring is in many cases neither difficult nor expensive. A ram costing perhaps \$10 at point of shipment and a few hundred feet of pipe are the essentials. The yield obtainable is dependent on several factors—the fall from the spring to the ram, the height at which the water is to be delivered, and the distance of the ram from the spring and the point of delivery. A simple formula for rough calculations is one-seventh of the flow to four times the head—that is a ram fed by a flow of 7 gallons per minute under 7 feet head will elevate 1 gallon per minute to a height of 28 feet, or 2 gallons to a height of 14 feet. The smallest rams installed require at least $1\frac{1}{2}$ gallons of water per minute for 3 feet of fall.

Objections are sometimes made to rams and tanks. The commonest is that by storage the water becomes unpalatable. Against this is the convenience of tap water. Between a well-situated spring and a dug well situated and curbed as too many are, the sanitary advantages are all with the spring. The main point in installing a ram is to have ram and pipe large enough to handle the water easily. Failure to measure the quantity of water available and the use of too small equipment are the chief causes of disappointment with new installations.

COLLECTING TUNNELS AND DRAINS

General statement.—The point where the upper surface of the ground water, or where some water-bearing sand reaches the face of a bluff or

terrace scarp, is frequently more or less hidden by wash. Hence it has happened that a small visible flow has been utilized when a larger yield could have been had by a little digging in a better situated or more convenient place not far distant. Where seeps on the faces of bluffs cause landslides that may destroy the beauty of a dwelling site, or do other damage, a small outlay of labor may not only stop the danger but develop a liberal supply of water less liable to contamination than that obtained by dug wells on top of the bluff.

Mount Vernon collecting tunnels.—A good example of how to make the most of such springs is to be seen on the face of the 125-foot bluff at Mount Vernon, on the Potomac. Here small flows and seeps of water that emerge at 50 feet above tide from Potomac sands locally indurated to ferruginous sandstone, caused slips of overlying clay beds which threatened serious injury to the premises. The bluff shows the following section:

Section of the bluff at Mount Vernon on the Potomac.

Group and formation	Material	Thickness	Depth
COLUMBIA, Sunderland	Soil	1	1
	Gravel	7	8
POTOMAC	Dry red clay	20	38
	Brown and yellow clay.....	25	63
	Putty clay, pockets of water.....	2	65
	Sand and sandstone indurated by iron near face of the hill where tree roots reached water; water-bearing at base	10	75
	Dry blue clay.....	7	82
	Dry red clay.....	20	102
	Brown and yellow clay.....	10	112
	Dry putty clay.....	1	113
	Dry sandstone, no water at contact with clay below	4	117
	Blue clay	6	123

Under the direction of William Archer tunnels 6 feet high and $3\frac{1}{2}$ feet wide were run nearly east and west in the 7-foot bed of blue clay below the sand and indurated sandstone. The first tunnel, which carried 2 feet of blue clay in the headings, was driven east 279 feet on a grade of 2 inches in 100 feet, and cut all seeps on clay level at right angles. At a sudden V-shaped depression, which carried much water, an underdrain $4\frac{1}{2}$ feet deep and $2\frac{1}{2}$ feet wide was dug. In this ditch 2-inch tiles were laid on 3 feet of rammed gravel, and covered with coarse washed gravel. Another tunnel was driven west 121 feet and filled with gravel. In August, 1906, the long tunnel was flowing 10,500 gallons in 24 hours, and the short tunnel 7,500 gallons.

The flows from the tunnels go to brick catch-basins, thence to two rams situated 18 feet below. With both rams running, 2,500 gallons a day are pumped to tanks 150 feet above river level.

According to Mr. Archer, the tunnels have dried the face of the bluff for twice their length, have stopped land slips, and are an unqualified success. They seem to drain the overlying Columbia gravels as well as the spring bed. A 20-foot dug well on the terrace, 80 feet above the ditch, is said to have gone dry since the completion of the tunnels, and the water in another dug well 100 feet from the bluff has been preceptibly lowered.

In ordinary practice there is no need of tunneling to develop hill-side springs. A gravel-filled trench to the bottom of the water-bearing bed, a covered catch-basin, a ram and pipe are enough. Since the work can be done when other farm duties are not pressing the labor expense may be small. There are many seeps and wet spots along the higher terrace scarps and river bluffs in Tidewater Virginia that can be developed by a little trenching.

WELLS

With the lessened use of springs as sources of domestic water supply there has been a great increase in the number of wells, until now, in most rural communities, every house has its well. As the wells are sunk to recover underground waters that are found under very different conditions, they vary greatly in depth, diameter, and yield, but may be divided into four classes as follows: (1) Dug wells; (2) Bored wells; (3) Driven wells; (4) Drilled wells.

Dug wells.—At present, chiefly because of its low first cost, the dug well is the mainstay of a majority of the inhabitants of the Virginia Coastal Plain. Except in a few counties, or in exceptional locations, enough good water for the needs of an ordinary household can be had by a dug well close to the house and less than 50 feet deep, and the labor cost of such a well, dug at a time when other farm work is not urgent, is more or less nominal. In most parts of the tidewater country the only laborer specially employed is the digger, and he may ask but \$5.00 for digging 35 feet.

Wells dug for household supply are 3 to 6 feet in diameter. When sunk through firm loam and sandy clays that will stand without support, usually no lining is placed, except enough at the bottom to keep the sand in the water-bed in place. This lining is of 2-inch plank, 12 to 16 feet long. Where water lies near the surface the wells are often lined with plank or boards from top to bottom, and have circular, octagonal, or

square cross-sections. In some localities the sandy soils will not stand and wells must be lined throughout, even though water lies 40 feet below the surface.

The total cost, labor and materials included, for many a 35-foot well, wood casing, curb, rope, and bucket, has been under \$20.00. Wells cased with brick or tile cost more—the prices asked by well diggers for digging a well and placing brick, running from 50 cents to \$1.00 per foot of depth.

The usual method of lifting water from the dug wells is by bucket with rope or chain, and windlass or pulley. At a few wells sweeps are still used. At an increasing number of wells are wooden lift-pumps or iron force-pumps, but the bucket is found in at least four-fifths of the country wells.

The great majority of the pumps are operated by hand-power. In some localities windmills are used, and here and there are gasoline engines.

Open wells of the sort most often seen rank among the most effective spreaders of disease. Wayfarers and transient laborers handle the bucket with their dirty hands, small animals fall in, and all manner of impurities, such as the droppings of fowls that have had access to privies, or filth from the feet of laborers who have been working about manure heaps, are washed in at every heavy shower. If a bed that is water-bearing in wet weather is met part way down the walls of the well heave at that point, the casing deteriorates rapidly, and in a few years a break comes, with a rush of sand. Repairs are troublesome and may be more expensive than digging a new well. In such a case the old well is often filled carelessly, adding to the unsanitary surroundings of the new one.

A well should be considered a permanent investment, and if not lined throughout with tile or cement should have a water-tight lining for several feet from the top. The top should be covered with a good sloping platform, and a pump that does not need frequent priming should be put in, to avoid the contamination of the well water by any water used for priming.

Bored wells.—This term is here applied to wells dug with an earth auger. Such wells are usually from 8 to 12 inches in diameter, and can be sunk cheaply where soils are free from large boulders. Most are covered, have pumps, and are, if curbed with tile, superior to wood-curbed dug wells. They are of course cheaper than dug wells curbed with large tile but their reserve capacity is smaller. While not so good for obtaining supplies from beds that transmit water slowly, bored wells are much less liable to serious pollution than dug wells.

Driven wells.—Driven wells consist essentially of an iron pipe with a pointed cap, are usually 1½ or 2 inches in diameter, and are driven to a

water bed. They are particularly adapted to localities where soils are easily penetrated and water lies in loose, coarse, clean sands. Wells 10 feet deep or less may be driven by a maul. Wells over 20 feet deep are usually driven by a hammer worked by a block and fall. The extreme depth to which a pipe can be driven depends on the character of the soil, but may exceed 100 feet. If the subsoil clay is tough, an earth auger is used to make a hole for the pipe. The water enters the well through holes in the cap and near the bottom of the pipe. To keep out sand galvanized iron screens are sometimes used, and, if the sand is fine, screens of brass gauze as fine as 60 mesh may be needed.

Driven wells may be equipped with cheap pitcher pumps, costing \$2 to \$5, wood pumps, or force pumps, the latter worked by hand or by a wind-mill. The obtainable yield varies with the transmission rate of the water bed, depth to water, size of pipe, and the pump.

From a sanitary standpoint, a driven well is much superior to a dug or bored well. If the pipe is driven 10 feet or more below the lowest level of the water table, has a collar of concrete to hold it firmly and prevent surface water from working down along it, and is topped by a good pump, that does not need priming, a driven well is safe from surface pollution.

There are hundreds of driven wells $1\frac{1}{2}$ or 2 inches in diameter and 5 to 50 feet deep in the low terraces of the Virginia Coastal Plain. They are very numerous in Norfolk, Princess Anne, Accomac, and Northampton counties. With an ordinary pitcher pump the average yield is about 3 gallons per minute. The total cost of a driven well varies with the depth and the equipment. For wells 5 to 50 feet deep the cost ranges from \$3 to \$40.

Drilled wells.—Under this head are included all wells sunk by drilling rigs, whether of jet, rotary or percussion types. Diameters range from 1 to 15 inches; depths from 50 to over 2,000 feet.

In the tidewater counties the deeper wells—most of those over 50 feet and very nearly all over 100 feet deep—have been sunk by rigs of the jet type. In these a stream of water is forced down a hollow drill rod and washes up the material loosened by the reciprocating bit. If the beds penetrated are loose, casing must be placed as the boring advances. In firm, compact sandy clays the hole will stand without casing. If no hard layers or loose sands are encountered progress is rapid, and by hand power alone a depth of 400 feet can be reached.

Hand power rigs have light derricks made of wood or of iron pipe, and are worked by two or more men pulling on a rope leading over a head

pulley, the bit being rotated with a wrench. Two other men are needed to work a pump to force water down the rod through openings in the bit and up the casing, and wash out the drillings. In firm sands free from hard "rocks" a hand power jet rig put down a $1\frac{1}{2}$ inch hole 150 feet in half a day, but should one or more "rocks" be encountered, even though these be but a foot or so thick, a driller may be a week or two in completing a well.

Drillers have sometimes substituted horse for man power, but practically all wells over 300 feet are now sunk by rigs with gasoline or steam engines. With these rigs, wells 2 or 3 inches in diameter have been sunk over 1,000 feet through the Coastal Plain beds. Various types of gear are used for giving a reciprocating motion to the drill rod. A rig capable of sinking a 3-inch hole 1,000 feet requires the services of a driller and a helper. The rate of progress, hence the total cost of drilling, depends largely on the skill and resourcefulness of the driller. Hard beds give trouble, but rapid progress is made through firm sands.

For wells of large diameter, such as are needed for city supply or for the equipment of manufacturing plants, three types of drilling outfits have been used in the Virginia Coastal Plain; the jet, the rotary hydraulic, and the standard cable, all of which require for heavy work a driller, a helper, and one or two laborers.

The rotary hydraulic rig has a revolving bit down which water is forced. It is particularly suited for rapid advance through soft or unconsolidated deposits. The chief objection to its use in a district where the water-bearing beds are thin and have not been definitely located, is that a sludge of mud and water is used to plaster the sides of the hole to prevent sand beds from running. By keeping pressure on a pump and forcing down mud a driller need not place casing and can therefore make rapid progress; this tempts him to neglect possible water beds, particularly if he is working at so much per foot. One well in Tidewater Virginia, said to have been sunk by this process 1,000 feet without casing, was not a success, though flows were found at lesser depths by other wells in its vicinity.

The standard cable rig, the best type, all things considered, for going through rock, is not particularly adapted for work in the Coastal Plain sands and clays. In most localities the casing has to follow the bit closely, and even a careful driller may have great difficulty in getting through loose sands which sometimes rise in the casing 100 feet over night. Sudden inrushes of sand may bury the drill, causing vexatious delays. Again the frictional resistance of the sands may prevent the casing, after several

hundred feet are placed, from going down by its own weight; then it has to be driven and heavy driving may break it at some joint, causing its collapse and the loss of the well. All things considered the jet rig is perhaps the best of the types in use, though in places what is known as the California stove-pipe rig could be used to better advantage.

The actual cost of drilling a given well and the price asked by the driller may differ greatly. The driller assumes the risk of accidents and unforeseen delays, can not work all the year, and has to bear the expense of moving and setting up his rig. The drilling cost varies with depth, the rate of advance, the casing needed, etc. Where drilling is good the actual labor and power cost of a 1½-inch well 150 feet deep may be \$10; if hard "rocks" are struck the cost may be \$75. The cost of larger wells varies as widely. Under favorable conditions a six-inch hole can be sunk 1,000 feet for \$1 per foot, excluding casing, but more than one driller has lost money contracting to sink 500 feet for \$2 per foot.

The usual price for a cased six or eight inch well from 200 to 500 feet deep has been \$3 per foot.

Most of the small diameter wells are sunk on a "flow or no pay" contract. Where a driller knows that at a certain depth water can be struck having sufficient head to rise above the well mouth he will contract at a low figure, whereas in territory that is new to him, or where the surface elevation makes a flow doubtful, he will ask much more. Large diameter wells are usually sunk at so much per foot, the price increasing below certain depths, or under a contract to get a flow and complete the well for a certain price. Whether the owner is liable to lose more at the hands of an unscrupulous driller by contracting for a flow at an unnecessarily high price than by having the driller working at so much per foot, pass by water beds to run up the total cost, is a question. The fairest contract, where conditions are unknown, is one which protects the driller from loss and stimulates him to do his best. Such a contract should be at a certain price per foot, with a bonus for obtaining the desired flow within a given time, or above a given depth.

Speaking generally, the cost of a well may run from 10 cents to \$5.00 a foot, depending on the diameter of the well, the length of casing needed, and the material penetrated. The writer knows of a fine 1½-inch well 150 feet deep, that cost, casing and all, but \$18, and of a 6-inch well 1,000 feet deep that cost \$4,000.

The most expensive well ever drilled in Tidewater Virginia is the one sunk at Fortress Monroe in 1902. This had 15-inch casing to 720 feet,

12-inch casing to 1,200 feet, and 9-inch casing to 2,128 feet. From 2,128 to 2,250 feet no casing was placed. The contract price was \$34,820.

MAGNETIC WELLS.

The only magnetized well in the tidewater region to come to the writer's notice is that of J. M. Shackelford at Severn, in Gloucester County. At first the casing is said to have had magnetism enough to hold up a 10-penny nail, but in November, 1906, two years after the well was drilled, the magnetism was just sufficient to draw from the perpendicular a small iron key suspended from a ring.

The reason for the magnetic action of the casing is simple. The earth is itself a great magnet; the drill falling at right angles to what are known as the lines of force becomes magnetic, the jar of the bit helping the particles of steel in it to become polarized. By the scraping of the bit on the casing the latter is magnetized in much the same way as a knife blade is by rubbing it on a pocket magnet. The duration of the magnetic effect depends on the physical structure of the metal in the casing and on the original intensity of magnetization.

Claims that magnetic waters flow from such magnetized wells have been made, but have not been verified. The casing of the well at Severn is said to have shown a stronger effect when the water was running than when the flow was shut off. That such was actually the case seems doubtful.

YIELD OF WELLS

When the water in an open well is lowered by bailing or pumping the upper surface of the ground water is locally depressed, and under continued pumping falls until the increased rate at which the water enters the well from the surrounding sands by reason of the pressure toward it, equals the rate of bailing or pumping. The rate at which water flows to the well depends on the difference in pressure between the water at the instant it enters the well and the water in the surrounding sands, as measured by the local depression of the water table, and the ease with which the sands transmit water. As has been stated, every soil has a certain porosity determined by the size of the voids between the soil particles, and every soil has, at a given temperature and a given difference of pressure, a certain rate at which it will transmit water, called its transmission constant. The conditions governing flow to wells have been studied by Schlichter, among others, who says:

"The amount of water yielded by a common well or by a non-flowing tubular well is dependent first of all upon the degree of fineness of the material in the various strata from which the water is obtained. The size of the soil grains not only determines the rate at which water can be transmitted to the wells under a given head but it also determines the proportion of contained water the soil will freely part with. The fine-grained soils retain a considerable proportion of the water of saturation as capillary water even after free means of drainage are established, so that fine-grained materials will not only deliver water slowly but will furnish only a small total amount. Some quicksand is so fine that the waters can be pulled away from the fine grains only with the greatest difficulty."^a

The same general principles apply to artesian and flowing wells as to shallow open wells. The yield of water depends on the difference in pressure between the water in the well and the water in the sand, on the temperature (which for deep wells is unvarying), on the porosity, or rather the transmission constant of the sand, and on the thickness of the sand. These factors account for all the differences observed in the yield of flowing wells, except such as are due to faults in drilling or maintenance. Fine sands, imperfectly assorted sands, and clayey sands transmit water less freely than coarse, clean, evenly assorted sands, and coarse gravels transmit water still better. The boldest flows in the tidewater country come from beds of coarse, rounded sand or from beds of smooth gravel.

LOSSES OF HEAD OR YIELD IN FLOWING WELLS

Causes.—The commonest complaints of a well owner are that the water in his well will not rise as high as when the well was just completed, or that the yield is less, and that if he wants as much water as he had at first he must have a new well sunk. The causes of lower head and lessened yield are various, and the responsibility may rest on one or on many persons. The causes may be summarized thus:

- (1) Faults in sinking; such as (*a*) improper casing, (*b*) lack of screens.
- (2) Faults in maintenance; such as (*a*) neglect, (*b*) abuse.
- (3) Interference.

^aSchlichter, C. S., Field measurements of the flow of underground water, U. S. Geol. Survey, Bull. No. 140, p. 87.

FAULTS IN SINKING.

The desire of a driller to economize on casing has resulted in reducing the flow of many a well. Where the clayey Chesapeake or Pamunkey sands above the water bed would stand without casing it was customary for a driller to place casing through the overlying Columbia or Recent material and bottom it in the sandy clay, possibly using in all only a length, about 20 feet. Such work permitted (1) the sub-surface escape of water, by leakage, about the bottom of the casing, or the escape of water below the casing from a deep sand into a higher one; (2) the clogging of the well by material washed from the sides but too heavy to be carried up and discharged by the flow.

Some drillers instead of placing casing to the water-bed carry it down to an impervious layer, but leave a small pipe, usually the $\frac{3}{4}$ -inch drill rod, in the well. This diminishes the danger of the well clogging but does not prevent possible leakage outside the pipe, which only half fills the hole of water from the deep sand into a sand nearer surface.

Screens have been little used in small flowing wells on the western shore of the bay. Their use might diminish the possible yield, but would maintain the flow, of many wells sunk into loose sands and showing low initial heads. On the Eastern Shore screens are used at many wells because the loose sands and soft clays soon clog unscreened wells, or because at pumped wells the sands damage pump valves and cylinders.

FAULTS IN MAINTENANCE.

Neglect.—Most flowing wells, like non-flowing driven or dug wells, receive too little care from owners. Many flowing wells, particularly those of low head tapping loose sands, need to be cleaned occasionally. The sand can be washed out with a good force pump and enough pipe to reach the bottom of the well. A well with a screen is sometimes clogged by sand grains packing against the screen. In such a case the flow may be restored by forcing water down the casing, thus loosening the packed sand.

Abuse.—Under the head of abuse come dropping in pebbles or other objects too heavy for the water to lift, attempts at cleaning with a sash weight and string (a plugged well may be the result) and momentarily stopping the flow by the hand or otherwise. A momentary stoppage of flow may have no effect on some wells, particularly properly cased wells with high head, but at others it may permit loose sand in the casing or the bore hole to pack, thus greatly reducing if not cutting off the flow. Any

sudden interruption of flow in a well not cased to the bottom may loosen material above the water sand and clog the well.

Generally speaking, it is not advisable to shut off a flowing well, but where unrestricted flow may affect the head of nearby wells the flow may be reduced to a small fraction of the normal volume. The reason for not shutting off the flow entirely is that more than one well has had its flow reduced or cut off by children or older persons closing the pipe with their hands.

INTERFERENCE.

The total supply of water in the artesian sands of the Virginia Coastal Plain is practically inexhaustible, but it is easily possible to draw so much water from a particular part of a bed, especially if the bed be thin, that the head of the water in that part of the bed is decidedly reduced. Such reduction of flow has happened at various places along the Rappahannock River; also, and especially, at Colonial Beach and West Point.

At Colonial Beach the first artesian wells found water, at a depth of about 200 feet, that rose fully 20 feet above tide level, or above the surface at the highest points in town. Possibly 200 wells have been drilled in an area $1\frac{1}{2}$ miles long and half a mile wide. No restrictions have been put on flow and a few of the wells are pumped heavily. As a result the head of the water in the 200-foot sand has been so reduced that most wells in the center of the town do not flow at the surface, and many at lower elevations flow only at high tide. Many wells back from the water front have been cut off below the surface and now flow into basins 5 feet or so deep. The lowest wells, those along the shore, drain those on higher ground. The sinking of one well on the water front has stopped the flow of a neighboring well on ground a few feet higher. Many of the wells were poorly cased and there is probably much leakage underground. That this loss of head is purely local is shown by the high heads of wells tapping essentially the same horizon at points a mile or two from town.

At West Point where over 300 wells have been driven the loss of head has been even greater than at Colonial Beach, but conditions are more complicated. The city is on a point of land at the junction of the Mattaponi and Pamunkey rivers. There is a water-bearing sand at 120 feet and another at about 165 feet. Along the water front many wells have been drilled and allowed to flow without restraint. As a result wells on higher ground that formerly flowed now have to be pumped. The 120-foot sand that once furnished flows is now penetrated by many poorly cased wells

sunk to the 165-foot sand, and the water flows down these holes to the 165-foot sand and escapes from the river-front wells tapping the latter sand. The maximum local loss of head in the 165-foot wells has been about 15 feet; in the 120-foot sand even more. According to E. W. Wilkinson, a well sunk in 1884, and one of the first if not the first in the town, flowed at an elevation of 14 feet above surface, or 20 feet above tide. After about a year and a half, when a number of wells had been drilled, the flow decreased and now the well is pumped. Isolated wells above the city or across the rivers show undiminished heads.

The manner in which poorly cased wells and wells near river level have reduced the head of the water in the 120-foot and 165-foot sands at West Point is indicated in Fig. 7.

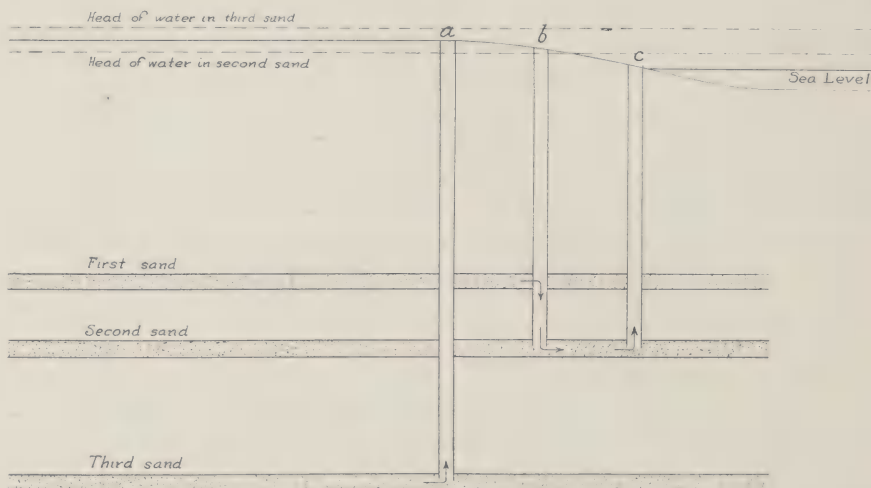


Fig. 7.—Diagram illustrating artesian well relations at West Point. *a*, properly cased well which obtains a flow from the third sand; *b*, improperly cased well on high ground, no flow; *c*, well at river edge; flows continually, draining third sand, also second sand through well *b*.

From an examination of several hundred flowing wells in the Coastal Plain of Virginia the writer ranks the causes of decline in yield as follows: (1) interference; (2) neglect; (3) improper casing; (4) abuse.

UTILIZATION OF SUPPLY.

The great majority of the flowing wells in Tidewater Virginia are of small diameter, 2 inches or less, and yield about 2 gallons a minute at the

well mouth. This yield with proper economy is liberal for an average household. In great manufacturing cities where the installation of meters on all service mains has reduced the consumption of water to actual requirements the daily consumption is as low as 50 gallons per capita. The average person drinks about 3 pints of liquids per day and 25 gallons per capita has been estimated as sufficient for all domestic needs. Hence a flow of 2 gallons per minute, or 2,880 gallons per day, if storage capacity is provided, will not only more than suffice for a household of average size, but the overflow piped to the barn will water many head of stock, allowing 8 gallons per head.

Yet at most places in Tidewater Virginia there is little effort toward economy. On the other hand, there are a few places, notably Tappahannock, where the superiority of the deep waters to those obtainable from dug wells is so much appreciated that wood or concrete tanks are built at some well mouths from which the water is piped to pumps or taps at two or three houses.

Rams at flowing wells.—Where a house and farm buildings stand on a terrace 25 feet or more above river or bay level and flows on the terrace are impossible, an abundant supply may be had for dwelling and barn by harnessing a hydraulic ram to a flowing well of good head below the terrace and piping the water to a tank. A flow of 5 gallons per minute at 10 feet above tide level can be had along many inlets on the lower courses of the rivers on the west side of Chesapeake bay. If properly placed and connected, to utilize 7 feet of this head, a ram costing possibly \$15 will afford 1 gallon per minute at 40 feet above the ram. There is little difficulty in thus making a flowing well pump its own water. The most essential feature of the equipment is a basin, small tank, or stand-pipe between the well and the ram; the ram should never be connected directly to the well. There are in Tidewater Virginia a number of wells with rams that give satisfactory service. Some failures reported were due to not determining in advance the available head and flow and the amount that could be delivered at the desired point; other failures were due to improperly placed or connected equipment.

SANITARY PROTECTION OF WELLS

In drilled wells there is ordinarily slight danger of pollution except from the top, because the tight iron casing protects against sub-surface contamination. Yet one can see wells that cost \$200 sunk to sands that yield beautiful water, into which all kinds of backyard refuse are washed

at every rain, simply because the top of the casing or the pump chamber is not properly protected, a defect remedied at trifling expense. Flowing wells, such as those in the Virginia Coastal Plain, are practically unpollutable, and it is to this fact that the improved health of particular communities after the development of artesian supplies has largely been due.

The greater the number of people that may use a well the more urgent the need of the well water being free from disease germs. Also it is evident that if many people use an open well there is more chance of some person who carries disease germs handling the bucket and thus contaminating the well water. Consequently, wells at churches, camp-meeting grounds, courthouses, and schoolhouses need to be dug and protected with more than ordinary care. Many cases of typhoid fever have been traced to such public or semi-public wells, and yet the precautions taken against the pollution of well water at many gathering places in the tidewater country are practically of no account. Usually the most that is done before a camp meeting is to clean the dug well. This is a wise precaution but does not lessen the chance of the water being polluted during the meeting. Absolute safety means making pollution impossible. This implies location with regard to natural conditions of drainage—most church and courthouse wells in the tidewater country satisfy this requirement—and then, if water can not be had by a driven well and a deep drilled well would be too costly, providing a water-tight casing extending several inches above and at least 5 feet below ground level, a water-tight cover and a good pump. The open well and the oaken bucket may appeal to sentiment but the tightly cased well and the force pump are far more sanitary.

Even though a drilled or driven well is properly sunk and has a good pump, occasional inspection is necessary to make sure of an unpolluted supply. A virulent outbreak of typhoid at one locality in the tidewater country was traced to the schoolhouse well. This well had been sunk to an artesian sand, the water from which rose to within a few feet of surface. As the artesian water was known to be excellent the well was not suspected until the coming of the fever, which attacked 40 per cent of those who drank the well water. Investigation showed that the casing had rusted through at ground water level, a few feet below surface, and in consequence the well for an unknown length of time had not drawn on the artesian supplies but on a polluted source.

PUBLIC HEALTH AS RELATED TO UNDERGROUND WATER SUPPLY.

Without accurately kept mortality tables covering a term of years, it is practically impossible to prove or disprove statements regarding changes in the death rate or in the prevalence of particular diseases at specified communities. Hence, statements regarding the effects of changes in the conditions of living in the smaller settlements and the rural districts of the Virginia Coastal Plain are of value only in so far as they are put forth by persons who are familiar with the conditions and are competent to judge. For this reason the testimony of local physicians is of decided value. In their opinion changes in sources of water supply in towns, villages, and on farms have been followed by definite changes in the prevalence of specific diseases, more especially typhoid fever and malaria. Following the lessening use of springs as sources of supply and the increasing use of unprotected dug wells, there was a marked increase in typhoid. The substitution of driven and drilled wells for open wells at particular villages has notably diminished the prevalence of this disease and lowered the death rate. In addition physicians living in widely separated communities claim that the development of artesian supplies in the lowlands along the rivers has practically freed many tracts from the malarial fevers for which they were once notorious.

MUNICIPAL WATER SUPPLIES**SOURCE OF SUPPLY**

Some of the towns and cities in the area covered by this report have waterworks that distribute surface water, a few have plants that draw on underground supplies. The surface water is variously obtained from rivers or ponds, the underground water from shallow or deep sources.

SURFACE WATER

Rivers and creeks are the more important sources of surface water. They are subject to great variations in volume of flow and quality of supply; at times of flood they contain much finely divided mineral matter in suspension or semi-solution, and are extremely turbid. Many of the surface waters are polluted; the large rivers by the sewage of cities, the creeks by drainage from privies, barnyards or cultivated fields. The ponds drawn on are as a rule less liable to pollution, but vegetable growths frequently make the water high-colored or give it an offensive smell and taste. In consequence, most of

the public supply systems include equipment for rendering the water more acceptable, ranging from simple settling basins to elaborate filtration plants.

UNDERGROUND WATER

Though the porous sands of the various Coastal Plain formations form great underground reservoirs, they are much less important as sources of municipal water supply than rivers and creeks. This is because there are few cities or towns of large size along the middle portion of the Virginia Coastal Plain where the underground waters, and more especially the artesian waters, are most readily available. The cities are chiefly on the western edge of the Coastal Plain, where flowing wells can not be had and the ground water supplies are not sufficient for the needs of large cities; or towards the seaward edge where the deep artesian water is not well suited for municipal use, and satisfactory shallow water is restricted to certain areas.

SUITABILITY OF SURFACE AND UNDERGROUND WATERS FOR MUNICIPAL NEEDS.

The belief that underground water is better, that is more healthful, than surface water is widely held, but rests on the sparkle, clearness, coolness and taste of well and spring waters rather than on careful investigations of their merits.

Surface waters are often badly polluted but settling and filtration render them innocuous; the water furnished by the supply systems of the larger cities in eastern Virginia is, from a sanitary standpoint, altogether superior to that obtained from many dug wells in villages. The deep artesian waters are unpolluted, but under a considerable part of the Virginia Coastal Plain they contain enough mineral salts to make them less suitable for boiler supply and other industrial purposes than filtered surface water. The latter, as a rule, contains little lime and the addition of the chemicals for precipitating finely divided matter does not increase the mineral content enough to affect the industrial value of the water as distributed. In general it may be said that nearly all of the public supply systems distribute good water, that is, water which satisfies sanitary and industrial requirements. In fact, most of the cities of Tidewater Virginia have reason to be proud of the excellence of their public water supplies.

NOTES ON CITY AND TOWN SUPPLIES

The city of Richmond owns its water supply system. James River receives the sewage of several cities and towns and is often very turbid.

The water is collected in a settling reservoir above the city limits and after purification is pumped to the mains and to smaller distributing reservoirs on high points in the city. Careful determinations of the variations in turbidity, and chemical and bacterial quality of the water were made during a number of years, and on the basis of the results the city installed a sedimentation and coagulation plant. The water after treatment is remarkably clear. The municipal waterworks in Manchester distribute James River water, collected above the city at a point opposite the intake of the Richmond city waterworks and purified by sedimentation and mechanical filtration.

Barton Heights, a suburb of Richmond, was supplied in 1910 with water obtained from a spring and from a well 759 feet deep.

Norfolk gets water from three distributing systems. The city waterworks, which supply most of the city, draw on small lakes in low ground northeast of the city; the sanitary surroundings of these in 1906 were good. Complaints of color and odor, caused by vegetable growths, led to the installation of a coagulation and filtration plant, and the water supplied is now satisfactory. To meet the prospective needs of the city other sources of supply have been sought. Part of Norfolk and several suburban towns, Lambert's Point, Ocean View, Huntersville and Lindenwood, are supplied by the Norfolk County waterworks, which get most of their supply from a system of driven and dug wells on a tract of land near the lakes that supply the city works. This ground water is of good quality and is distributed by a direct pressure system without filtering. To supply an increasing demand the company has investigated the development of surface waters similar to those distributed by the Norfolk City waterworks. The eighth ward of Norfolk, formerly the city of Berkeley, is supplied by the Norfolk, Berkeley & Suffolk Water Co. Most of the water comes from a system of shallow driven wells on a tract of land not far from Berkeley, but part comes from Smith's Creek (Lake Kilby) near Suffolk. The well water is of satisfactory quality but the quantity obtainable on the tract near Berkeley is insufficient for the prospective needs of the community.

The cities of Suffolk and Portsmouth are supplied by the Portsmouth, Berkeley & Suffolk Water Co., with Lake Kilby water. The water of Lake Kilby is high-colored and at times has an objectionable smell. The water distributed passes through a coagulation and sand-filtration plant which reduces the color and removes the odor.

The city of Newport News, the city of Phoebus, the town of Hampton, the Hampton Agricultural and Collegiate Institute, the National Soldiers'

Home, near Hampton, and the military post of Fort Monroe, are supplied with water by the Old Dominion Water & Power Co. This company has a large reservoir in Warwick County, controls practically all the watershed (about 1,500 acres) of the creeks feeding this reservoir, and endeavors to protect the watershed from pollution. Because of complaints of high color and disagreeable odor the company installed a coagulation and filtration plant (mechanical filters) and the water is now satisfactory.

The city waterworks of Petersburg distribute surface water obtained from Livetenant Run, a creek that empties into Appomattox River on the east side of the city. The watershed of the creek is open to pollution from dwellings, but the creek water is passed through a settling and coagulation basin and is filtered before distribution, consequently its quality is satisfactory.

Fredericksburg owns its distributing system, which obtains water from a canal of the Rappahannock Power Co., supplied by a dam on Rappahannock River three miles west of the city. The river is often very turbid and local conditions do not tend to improve the quality of the water passing through the canal, but a collecting reservoir at the pumping station permits decided improvement by sedimentation. From the collecting reservoir the water is pumped to a distributing reservoir on the heights south of the city. A considerable number of people in the city obtain water from the mains of the Aqueduct Company. This water comes from several springs, none of large size, on the high ground south of the city, and is generally of satisfactory quality.

Alexandria has city waterworks that distribute water from Cameron's Run, a creek on the south side of the city. The water is collected three miles west of the city and brought by a canal to a pumping station, whence it is forced to settling and distributing reservoirs on Grimes' Hill. The run water is often turbid, the water shed is inhabited, and conditions along the canal are not altogether satisfactory. However, the quality of the water is decidedly improved by sedimentation in the settling reservoir.

The city waterworks of West Point draw on artesian wells that tap sands 330 feet below surface. The sanitary excellence of this supply is not disputed, but its industrial value would be greater were the water less mineralized; it contains considerable bicarbonate and sulphate of soda and in boilers has a tendency to foam.

The town of Franklin has a public supply system drawing on Blackwater River. The water is pumped from the river to a tank on a high tower; it is a good boiler water but at times is objectionable for drinking.

The Smithfield supply is from a pond on a small creek three miles west of the town. It is not filtered, but the small watershed of the creek is sparsely settled, and except for vegetable growths the quality is satisfactory.

The town of Emporia distributes Meherrin River water. An attempt to get water by a deep well gave unsatisfactory results.

Practically all the water distributed by the municipally owned system of the town of Cape Charles comes from driven wells varying in depth from 30 to 90 feet. The supply is not altogether satisfactory, partly because the wells are close to tidewater. The water is hard and forms scale in boilers.

The Onancock waterworks draw on driven and drilled wells less than 75 feet deep, and on a large dug well. The water, while slightly hard, works well in boilers, and except for the possibility of polluted water entering the dug well, the sanitary surroundings in 1906 were good.

The military post of Fort Myer, west of Alexandria, is supplied with filtered Potomac River water. Fort Hunt on Potomac River, below Alexandria, obtains excellent water from an artesian well.

A summarized statement of information collected regarding the public water supply systems of the Coastal Plain towns and cities appears in table 2.

TABLE 2.—*Municipal water supplies in the Coastal Plain Province of Virginia.*

City	Owner	Source	From what distributed	Capacity of reservoir (gal.)	Elevation of reservoir or standpipe above town (feet)	How distributed
Alexandria	City	Cameron Run	Reservoir	16,000,000	55-95	Gravity
Ashland		Wells	Standpipe			
Barton Heights	Town	Springs and wells	Standpipe	50,000	30-60	Direct pressure
Cape Charles	City	Wells	Standpipe	50,000	60	Direct pressure
Franklin	Town	Blackwater River	Standpipe	80,000	110-125	Gravity and direct pressure
Fredericksburg	City	Rappahannock River	Reservoir	4,000,000	125	Gravity and direct pressure
Manchestera	City	James River	Standpipe	11,000,000	20-240	Gravity and direct pressure
Newport News	Newport News Light & Water Co.		Standpipe	128,000		Gravity and direct pressure
Norfolk	Norfolk County Waterworks Co.	Wells	Standpipe	430,000,000	200	Direct pressure and gravity
	City	Lakes	Standpipe	305,000	100	Direct pressure
	Portsmouth, Berkeley & Suffolk W. Co.	Wells	Reservoir			Direct pressure
			Standpipe		100	Gravity and direct pressure
Onancock	Town	Wells	Standpipe	50,000	80	Gravity and direct pressure
Petersburg	City	Livetenant Run	Reservoir	3,000,000	40-150	Gravity and direct pressure
Portsmouth	Portsmouth, Berkeley & Suffolk W. Co.	Smith's Creek	Standpipe		100	Gravity and direct pressure
Richmond	City	James River	Reservoir and standpipe	150,000	285	Gravity and direct pressure
			Standpipe	40,000,000	15-155	Gravity
				9,000,000		
Suffolk	Portsmouth, Berkeley & Suffolk W. Co.	Smith's Creek	Standpipe		110-170	Gravity and direct pressure
Smithfield	Town	Creek	Standpipe		40-70	Gravity
West Point	City	Wells	Standpipe	65,000	70-90	Gravity and direct pressure
			Cistern	20,000		

^aNow a part of the city of Richmond.

TABLE 2. (Continued.)—Municipal water supplies in the Coastal Plain Province of Virginia.

City	Length of mains (miles)	No. of taps	No. of fire hydrants	No. people supplied	Population of city in 1910	Daily consumption (gal.)	Max. capacity of pumps (gal.)	Domestic pressure (lbs. per sq. in.)	Fire pressure (lbs. per sq. in.)	Purification system
Alexandria . . .	17.3	3,520	160	3,300 ^b	15,329	1,000,000	2,100,000	20-35	20-35	Sedimentation
Ashland . . .					1,324					None
Barton Heights . . .					1,388					None
Cape Charles . . .	1.5		20	1,100	1,948	60,000		25	50 (?)	None
Franklin . . .	3.5	150	57	1,000	2,271	80,000	1,440,000	50	125	None
Fredericksburg . . .	28.0	1,431	92	1,560 ^b	5,874		1,000,000	40-55	55-90	Sedimentation
Manchestera . . .	16.0	1,730	75		9,715	1,435,770	2,250,000	49-90	49-90	Coagulation
Newport News . . .		2,400	180		20,205					Coagulation and filtration
Norfolk . . .	80.0		40	1,400	67,452	1,000,000	3,500,000	40		None
			24				22,000,000	30		None
							1,500,000			
Onancock . . .	1.5	75	30		1,001		168,000	40-55	55-90	None
Petersburg . . .	28.0	2,900	280	15,000	24,127	800,000	3,500,000	14-60	14-60	Sedimentation and coagulation
Portsmouth . . .	75.0		220		33,190		10,000,000			Coagulation and filtration
Richmond . . .	133.0	18,000	1,000		127,628	12,474,000	20,500,000	8-83	8-83	Sedimentation and coagulation
Suffolk . . .			52		7,008		12,000,000			
Smithfield . . .					1,278					None
West Point . . .	3.5	67	36		1,397		430,000	43	75 (?)	None

^aNow a part of the city of Richmond.^bRate payers.^cPopulation as of 1900 census.

MINERAL WATERS

The term, mineral water, as commonly used, implies either water having therapeutic value or water differing decidedly from that obtained from the springs or shallow wells of a given region. Some waters, classed as mineral, are very soft and pure, and owe the esteem in which they are held largely to their low mineralization. Others are so highly charged with various substances that they are offensive to taste and smell and have a powerful physiologic action.

As has been stated the potable underground waters of the Virginia Coastal Plain differ widely, the amount of dissolved mineral matter they contain varying from less than 50 to over 9,000 parts per 1,000,000. Many are especially light and pleasant table waters; a few are so strongly mineralized that they should be drunk only under the advice of a physician.

In general, the shallow waters differ more than the deep waters, yet they are distinguished by the predominance of calcium and magnesium salts. Some springs of shallow source contain iron and aluminum salts in sufficient quantity to have therapeutic value, others are notably free from such compounds. Most of the spring waters that have been marketed are of such low mineral content that they are to be classed as table rather than as medicinal waters.

Outside of Southampton and Alexandria counties and a part of Essex County the deep waters so far developed are characterized chiefly by the presence of sodium and potassium salts, especially the bicarbonates. Few of these waters have been marketed, partly owing to lack of suitable transportation facilities. Some of those exploited contain sodium and potassium bicarbonates in sufficient proportion to be of therapeutic value.

The following list includes wells and springs from which water has been shipped in a commercial way at times during the past five years:

Beaufort Lithia Spring.....	Chesterfield County
Bellfont Lithia Spring.....	Chesterfield County
Buckhead Lithia Spring.....	Chesterfield County
Campfield Lithia Spring.....	Chesterfield County
Cappahonk Lithia Spring.....	Chesterfield County
Days Point Artesian Lithia Spring.....	Isle of Wight County
Diamond Spring	Princess Anne County
Erup Mineral Spring.....	Alexandria County
Fonticello Lithia Spring.....	Chesterfield County
Holly Lithia Spring.....	Chesterfield County
Hume Spring	Alexandria County
Landale Mineral Spring.....	Norfolk County
Mico Water	Alexandria County
Mulberry Island Chloride Lithia Water....	Warwick County
Trepho-Lithia Water	Surry County
Powhatan Spring	Alexandria County
Virginia Lithia Springs.....	Chesterfield County
White Oak Spring.....	Norfolk County

Other springs and wells than those named have in years past furnished water for sale, and a few have been more or less extensively exploited.

The list of producers shows that mineral springs are apparently confined to a few counties, seven of the eighteen springs named being in Chesterfield County, four in Alexandria County, and two being in Norfolk County. This localization, however, simply means that most of the commercial springs are near cities in which there is a demand for agreeable drinking water. Thus the Chesterfield County springs had their commercial beginnings in shipments to Richmond, and those in Alexandria County in shipments to Washington, at a time when the public supplies of both Richmond and Washington were often turbid and were regarded with suspicion by many people. The chief market for the springs in Norfolk County is the nearby city of Norfolk.

There are few sanatoriums or large hotels utilizing the alkaline artesian waters for the treatment of disease, but a large amount of water that might be designated as "mineral" under any usage of that term, is obtainable from artesian wells along the lower courses of Potomac, Rappahannock, and James rivers, and at least one city, West Point, distributes by a public supply system an alkaline bicarbonate and sulphate water that is claimed to have decided merit in the treatment of certain disorders of the stomach, liver and kidneys.

VALUE OF MINERAL WATERS

The total value of the mineral water reported sold by the springs and wells named in the preceding list amounted to \$33,000 in 1910. In addition to these sales several of the springs used large amounts in the manufacture of sweetened beverages.

DEEP WELLS IN CRYSTALLINE ROCKS.

General statement.—All the flowing wells of Tidewater Virginia tap waters that circulate through pervious beds in sedimentary deposits. Along the western edge of the Coastal Plain, a considerable number of wells have been sunk through the comparatively thin, sedimentary beds and have obtained water from the underlying crystalline rocks.

These rocks are hard, dense and without pervious beds. The water does not move through minute interstitial spaces but through relatively free passages, joint cracks which intersect the mass of the rock at various angles. The joints are of two orders, those roughly parallel to the upper surface of the rock or sheet joints, and those which are steeply inclined. Near surface

the sheet joints are much nearer together and more open than at a depth of several hundred feet. The vertical joints do not disappear as rapidly with depth, but as a rule grow narrower below; yet they do not extend downward indefinitely. Since the water lies in cracks and crevices that intersect irregularly there is nothing regular in its occurrence. Success in drilling depends on striking a crevice, and the wider and longer the crevice, and the greater the number of crevices it intersects, the larger the yield. One well may find water at a certain depth, while another, a few feet distant, may go twice the depth and find none; one well may strike a crevice carrying water fed to it from some distance through a series of connecting crevices; another may strike at over 1,000 feet a crevice containing water that comes almost directly from the surface and possibly from close to the well mouth. The general character of the circulation in the crystalline rocks is shown by the accompanying diagram.

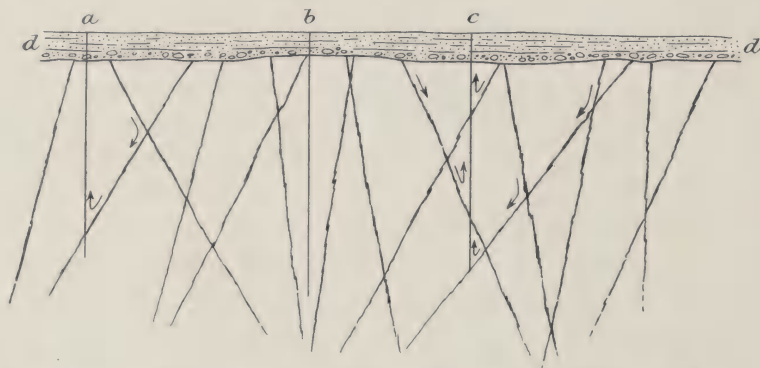


Fig. 8.—Diagram illustrating circulation of water in crystalline rocks, and well supply. (a) Deep well striking water that enters near well. (b) Deep well finding no water. (c) Deep well striking several crevices. (d) Unconsolidated material.

For the above reasons deep wells in crystalline rocks are considered by themselves, and facts relating to them are tabulated separately. Also, as the results of deep drilling in the vicinity of Richmond throw light on the occurrence of water in similar rocks and the prospects for deep wells in a strip of country extending from Maine to Georgia, some data collected in the course of field work are here discussed in detail.

WELLS NEAR RICHMOND

General conditions.—Richmond is situated at the “fall-line;” the resistant crystalline rock, a gray hornblende granite, outcrops in the bed of James River and causes rapids. In the low ground along Shockoe Creek and Gillies Creek the granite is overlain by Potomac sands and gravels; on the higher ground in the central and north parts of the city by Chesapeake dark sandy clays or marls, and along James River near the rapids by Columbia cobble beds and loams. The James is tidal to the foot of the rapids but the high Sunderland plain on which much of the city is built has an elevation of from 175 to over 200 feet. Hence, elevations of well mouths differ greatly and though a few wells were started almost directly on granite, others went through over 100 feet of loam, clay, and sand before striking hard rock.

Because of differences in surface elevation there are differences in the depth below surface at which water stands. In wells on high ground in the center of the city, water level is over 100 feet below surface. As most of the wells are pumped intermittently and few give large yields, deep well pumps are generally used. In some of the wells the pump barrel is 300 feet below the well mouth. The waters show wide differences in composition and have no general resemblance; two or three wells seem to draw on the same system of joint cracks, and one well yielded water unlike any other in Tidewater Virginia. Particulars are summarized in the accompanying table; only those wells that are of especial interest are discussed at length.

WELLS NEAR RIVER FRONT

Richmond Paper Co.—One of the first deep wells at Richmond was that of the Richmond Paper Co., drilled near the corner of Byrd and 9th Streets, in 1884. Water which rose to within 60 feet of surface, elevation 83 feet, was found at 250 feet, but it was sulphur-bearing, pitted boilers, and contained so much iron that it could not be used in bleaching rags, consequently the well was abandoned.

Albemarle Paper Co.—Another early well was that of the Albemarle Paper Co., on the river bank near Hollywood cemetery, put down like that of the Richmond Co., to get water more suitable for making paper than that obtained from the often-turbid James. It was started 10 feet above the river and found a small crevice at 225 feet from which water rose to about river level. The yield is so small, about 25 gallons per minute, that

little use is made of the well except for drinking and washing filters. For boilers and for paper-making the company filters some 500 gallons per minute of river water.

Other wells.—In addition to the wells of the Albemarle and the Richmond paper companies, there are a number of others near the river, including those of Kingan & Co., the Merchants Cold Storage and Ice Co., and the Transparent Ice Co. Depths vary from 248 to 703 feet and yields from 15 to 210 gallons per minute, the deepest well giving the smallest supply. At the Kingan well, according to report, the drill dropped over 1 foot when the water-bearing crevice was reached. At these wells there is a relatively thin cover of earth, at some wells mostly made ground, above bed rock, and as suggested by Darton^a they may yield surface water in part, though in most wells the character of the supplies indicates a deeper circulation. The waters contain enough lime and magnesia salts to make them bad for boiler use and they are utilized for condensing only. That from Kingan & Co.'s well has a sulphur odor, a flat taste, and is purgative; it is said to be so corrosive that ordinary casing lasts only 3 months and heavy galvanized casing but 3 years.

The analyst gave the following partial analysis with the results expressed as hypothetical combinations. The determinations have been recomputed to parts per 1,000,000.

Partial analysis of water from 428-foot well of Kingan & Co.

(Froehling & Robertson, analysts.)

	Parts per 1,000,000
Total solids	779.
Silica (SiO ₂)	31.5
Alumina and iron oxides (Al ₂ O ₃ + Fe ₂ O ₃)	18.
Calcium carbonate (CaCO ₃)	175.
Calcium chloride and sulphate (CaCl ₂ + CaSO ₄)	181.
Magnesium chloride (MgCl ₂)	107.
Alkaline chlorides and sulphates	267.

WELLS NEAR THE CENTER OF THE CITY

Hotel Jefferson.—An interesting series of wells is that drilled on high ground, near the center of the city and northward, for the three hotels and the apartment house named below. All are 8 inches in diameter and range in depth from 365 to 702 feet. As the table shows, the depths to water and

^aDarton, N. H., Artesian well prospects in the Atlantic Coastal Plain, U. S. Geol. Survey, Bull. No. 138, p. 178.

the height of the water level differ considerably, after due allowance is made for difference of elevation. The record of the Hotel Jefferson well is as follows:

Record of 445-foot well at Hotel Jefferson.

Group or formation	Material	Thickness	Depth
COLUMBIA			
Sunderland	"Drift soil"	41	41
	Gravel	2	43
CHESAPEAKE	Yellow clay	2	45
Calvert	Black clay	30	75
	Sand	15	90
	Sand, marine shells and a little water	12	102
	Blue clay	16	118
PRE-CAMBRIAN	Soft granite	5	123
	Hard and soft granite, water at 410 to 438 ft.	322	445

The well is said to be cased to 400 feet. The water rises to within 60 feet of surface, elevation 180 feet, but to obtain a yield of 60 gallons per minute the pump barrel had to be placed near the bottom of the well. The water is used at the table and for other purposes about the hotel but not for boiler supply. The following analysis, recalculated to express results in ionic form, was furnished by the manager.

Analysis of water from 445-foot well at Hotel Jefferson.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	173.
Silica (SiO_2)	38.
Iron and aluminum oxides ($\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$)	0.5
Calcium (Ca)	30.
Magnesium (Mg)	8.6
Sodium (Na)	6.2
Potassium (K)	1.2
Carbonate radicle (CO_3)	51.
Bicarbonate radicle (HCO_3)	not reported
Sulphate radicle (SO_4)	33.
Chlorine (Cl)	4.5

Chesterfield Apartments.—At the Chesterfield Apartments well, elevation 195 feet, the water, which was found at 230 feet down, stands 150 feet below surface but the yield is so free that the level is lowered only slightly by steady pumping. The apartments in 1906 used no city water at

all. The following analysis, recomputed from one obtained from the manager, indicates that the well water contains bicarbonates of lime and magnesia as principal substances in solution, and considerable silica.

Analysis of water from 365-foot well at Chesterfield Apartments.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	287.
Organic matter	5.9
Silica (SiO_2)	47.
Aluminum (Al)	0.5
Iron (Fe)	0.5
Manganese (Mn)	0.17
Calcium (Ca)	29.
Magnesium (Mg)	12.
Sodium (Na)	18.
Potassium (K)	3.7
Lithium (Li)	0.01
Strontium (Sr)	0.24
Iodine (I)	0.009
Bromine (Br)	trace
Arsenic (As)	trace
Bicarbonate radicle (HCO_3)	138.
Sulphate radicle (SO_4)	26.
Phosphate radicle (PO_4)	0.8
Chlorine (Cl)	6.1

Murphy's Hotel.—At Murphy's Hotel are two wells; one is said to be 450, the other 702 feet deep. The second well had not been put in service when the data for this report were collected. The first well, elevation 175 feet, struck rock at a reported depth of 125 feet. The water level is given as 100 feet below surface and the yield as 40 gallons per minute. The well is said to be cased for 350 feet, and the pump plunger is at 390 feet. The water is used for drinking and cooking, and has been bottled for table and medicinal use as Granite Lithia Water; though used in a boiler it is not satisfactory for that purpose, foaming somewhat. A series of analyses made by Otto Meyer^a in 1904 showed the presence of radium and traces of several rare earths and of tin, copper, and nickel. The principal substances in solution, however, seem to be bicarbonates of calcium and magnesium. In general the water is much like that from the Chesterfield Apartments well. The following analysis, recomputed from that furnished by the analyst, is given for comparison.

^aMeyer, Otto, Radium in water from a deep well, Sci. Amer., 1904.

Analysis of Granite Lithia Water; well at Murphy's Hotel.
(Henry Froehling, analyst.)

Determination	Parts per 1,000,000
Total solids	196.
Organic matter	0.82
Silica (SiO ₂)	34.4
Aluminum (Al)	0.3
Iron (Fe)	0.31
Manganese (Mn)	0.063
Calcium (Ca)	21.
Magnesium (Mg)	9.5
Sodium (Na)	21.9
Potassium (K)	5.9
Lithium (Li)	0.015
Strontium (Sr)	0.10
Barium (Ba)	0.04
Iodine (I)	0.002
Carbonate radicle (CO ₃)	70.
Phosphate radicle (PO ₄)	0.19
Sulphate radicle (SO ₄)	24.
Nitrate radicle (NO ₃)	0.15
Chlorine (Cl)	6.6

Richmond Hotel—The well at the Richmond Hotel, elevation 157 feet, struck a crevice yielding a large supply, said to be 300 gallons per minute; the depth to water could not be ascertained from the engineer in charge of the plant, but the pump plunger is 250 feet below surface. The water, which is used for all purposes, is more mineralized than that from the Chesterfield Apartments and Hotel Jefferson wells, containing more soda and potash as well as sulphates and bicarbonates.

Analysis of water from 572-foot well at Richmond Hotel.
(Froehling and Robertson, analysts.)

	Parts per 1,000,000
Total solids	702.
Silica (SiO ₂)	28.
Aluminum (Al)	1.10
Iron (Fe)	0.18
Calcium (Ca)	68.
Magnesium (Mg)	30.
Sodium (Na)	68.
Potassium (K)	29.
Lithium (Li)	0.01
Strontium (Sr)	0.02
Barium (Ba)	0.05
Manganese (Mn)	0.03
Iodine (I)	trace
Bromine (Br)	trace
Bicarbonate radicle (HCO ₃)	182.
Sulphate radicle (SO ₄)	232.
Phosphate radicle (PO ₄)	0.25
Chlorine (Cl)	63.

WELLS IN THE NORTHWESTERN PART OF RICHMOND AND IN OUTLYING
DISTRICTS TO THE NORTHWEST

A notable example of the uncertainty that attends the search for water in crystalline rocks is presented by three wells 550 to 650 feet deep at the Home Brewing Co. brewery, elevation 182 feet. These wells lie in a north-east line; the first well (8 inches), sunk in 1894, yields about 60 gallons per minute, and the barrel of the deep-well pump is over 400 feet below surface though normal water level is about 125 feet below; the second of smaller diameter (6 inches), 50 feet northeast of the first, sunk in 1899, gave but 5 gallons a minute when completed and has been dynamited several times at different depths without any increase in yield; the third (8 inches), 75 feet southwest of the first, is dry. The supply from the first two wells is used for condensing, brewing, and washing, but not in boilers as it scales badly. The company furnished an analysis of the water from the first well; this has been recomputed to express results in ionic form.

Partial analysis of water from 550-foot well of Home Brewing Co.

(First Scientific Station for the Art of Brewing, analyst.)

	Parts per 1,000,000
Total solids	448.
Organic and volatile	20.
Iron (Fe)	large traces
Calcium (Ca)	62.8
Magnesium (Mg)	12.6
Sulphate radicle (SO ₄)	144.
Chlorine (Cl)	24.8
Nitrate radicle (NO ₃)	none
Nitrite radicle (NO ₂)	none

In the vicinity of the old State Exposition grounds are several wells of note. One, 8 inches in diameter, at the packing plant of W. S. Forbes, is said to be 400 feet deep and to yield, with the pump plunger 340 feet below surface, 300 gallons per minute, sufficient for all needs of the plant in 1906. The water is said to be remarkably good for boiler supply. A low mineral content is shown by the following analysis, recomputed from that furnished by the chemist.

Analysis of water from deep well of W. S. Forbes.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	92.0
Organic matter	8.0
Silica (SiO ₂)	15.0
Iron (Fe)	0.4
Calcium (Ca)	4.0
Magnesium (Mg)	0.2
Sodium (Na)	22.0
Potassium (K)	not determined
Carbonate radicle (CO ₃)	25.0
Bicarbonate radicle (HCO ₃)	not determined
Sulphate radicle (SO ₄)	12.0
Chlorine (Cl)	5.3

A well said to be 385 feet deep at the Richmond Union Stock Yards, about 250 yards east-northeast of the above well, obtained but 5 gallons per minute and is said to have been affected by pumping at the Forbes plant.

Another 8-inch well not far away, that of the Southern Stove Works, about 300 feet deep, is said to yield 200 gallons per minute of an excellent boiler water that is used for all purposes about the works. In recomputed form, an analysis made by Henry Froehling for the company shows the following radicles:

Analysis of water from deep well of Southern Stove Works.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	319.
Silica (SiO ₂)	26.
Iron (Fe)	0.4
Aluminum (Al)	0.3
Calcium (Ca)	2.7
Magnesium (Mg)	0.7
Sodium (Na)	76.
Potassium (K)	3.6
Lithium (Li)	trace
Carbonate radicle (CO ₃)	not determined
Bicarbonate radicle (HCO ₃)	183.
Sulphate radicle (SO ₄)	17.
Arsenate radicle (As O ₄)	trace
Nitrate radicle (NO ₃)	0.8
Chlorine (Cl)	8.5
Bromine (Br)	trace
Iodine (I)	trace

Northwest of the city, in the vicinity of Ginter Park, several deep wells have been sunk which vary in the amount of water obtained. One on the estate known as Westwood went 900 feet, passing through Columbia and Chesapeake deposits to 108 feet and through granite below. The yield was but 5 gallons per minute; another on the same estate after going through 118 feet of sedimentary beds and 350 feet through granite obtained 50 gallons. At the estate known as Westbrook a well 306 feet deep obtained 50 gallons per minute of good water after going through sedimentary beds for 96 feet and granite for 210 feet; whereas another well, 322 feet deep, on the Bloomingdale Stock Farm, got 25 gallons per minute after passing through 123 feet of Coastal Plain deposits and 199 feet of granite.

The best well in this section supplies Ginter Park. It is 8 inches in diameter and 357 feet deep. Granite was struck at 123 feet. In 1906 about 60,000 gallons daily were pumped from the well for residences and for the Union Theological Seminary. The water was tried at a large laundry but proved unsatisfactory because of its hardness; it contains a considerable amount of sulphates. An analysis made for the owner, recomputed to express results in ionic form, follows:

Analysis of water from deep well at Ginter Park.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	626.
Total scale-forming matter.....	219.5
Organic and volatile matter.....	6.6
Silica (SiO_2)	28.
Oxides of iron and alumina ($\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$).....	1.2
Calcium (Ca)	55.2
Magnesium (Mg)	11.1
Sodium (Na)	128.
Potassium (K)	8.5
Chlorine (Cl)	37.0
Carbonate radicle (CO_3)	87.
Sulphate radicle (SO_4)	263.
Nitrate radicle (NO_3)	0.18

WELLS SOUTH OF RICHMOND.

At the works of the American Ether Co. just south of the city, a 407-foot well on low ground near Almond Creek is said to have gone through "earth" for 117 feet and "rock" for 293 feet. Potomac cobble beds and soft sandstones outcrop nearby in the creek bed, and the greater part of the "earth" is probably Potomac material. The well developed a large

supply, reported to have been 200 gallons per minute. This water at first was good but after some time became remarkably saline, and so corrosive that it could not be used even for condensing. The following analysis, recomputed from one made by the former chemist of the company, shows the unique character of the water:

Water from 410-foot well of American Ether Co.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	1610.
Sand and silica	32.
Oxides of iron and alumina ($\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$)	16.
Calcium (Ca)	16.
Magnesium (Mg)	8.9
Sodium (Na)	580.
Carbonate radicle (CO_3)	86.
Sulphate radicle (SO_4)	93.
Chlorine (Cl)	778.

An 8-inch well at Curle's Neck, 15 miles south of Richmond, went through Coastal Plain deposits to 311 feet, and into granite 414 feet; when completed it yielded only 9 gallons per minute. It was dynamited with the result that steady pumping for three weeks at the rate of 100 gallons a minute lowered the water level only a little. A sanitary analysis made for the owner contained these determinations:

Partial analysis of water from 710-foot well of C. H. Senff at Curle's Neck.

(J. A. Deghuee, analyst.)

	Parts per 1,000,000
Total solids	234.
Volatile solids	12.
Hardness, equivalent to CaCO_3 , before boiling.....	6.0
Hardness, equivalent to CaCO_3 , after boiling.....	3.0
Chlorine	37.5

EMPORIA.

At Emporia on a river terrace 40 feet above sea level, just outside the western edge of the Chesapeake deposits, is an 8-inch, 600-foot well sunk for town supply. The well entered granite at 6 feet and struck crevices at 62, 370 and 470 feet, the last being the most important. The water is reported to stand 10 feet below surface. The supply is said to be free; pumping at the rate of 100 gallons per minute lowered the water 20

feet. Only 28 feet of casing, it is stated, was put in the well. The quality of the water is reported to have been unsatisfactory and the town is supplied with river water.

PROBABILITY OF FINDING WATER BY DEEP WELLS.

The accompanying list undoubtedly omits some rock wells 200 feet deep or over that have been drilled in and near Richmond; but it probably includes the majority, and the omissions are chiefly unsuccessful wells. Drillers are liable to omit mention of dry holes when telling of the wells they have sunk, and some pursue the mistaken policy of claiming, if there is a chance of closing a contract at so much per foot with no guarantee as to yield, that they can get water anywhere. Owners do not advertise a failure and the present holder of a property may have no knowledge of a well drilled some years ago. Hence the total number of unsuccessful wells is hard to ascertain. The list tabulated, however, is long enough to serve as a basis for estimates valuable to persons contemplating deep wells for considerable supplies of water at points along the western edge of the Coastal Plain where crystalline rocks occur having the general character of those near Richmond. The facts are as follows:

(1). Of the deep wells in crystalline rocks 2 were dry or gave too little water to be of use; 7 gave, estimated or measured, 5 to 25 gallons; 16, 26 to 100; 4, 101 to 200; and 2 over 200 gallons per minute. Or, 5 gave 5 gallons or less, making the proportion of commercially successful wells over 80 per cent.

(2). Of the 22 more successful wells, 15 or nearly 70 per cent went less than 500 feet into "granite" and 1 went less than 200 feet.

(3). Of the 17 wells yielding 50 gallons per minute or over, 6 were on high ground, 6 on low ground, and 5 on hillsides, showing that yields bear little relation to the situation of wells.

ANALYSES OF WATERS FROM WELLS IN CRYSTALLINE ROCKS NEAR RICHMOND.

The following table gives all the available analyses of the wells mentioned; it includes partial analyses and determinations of chlorine, total and volatile solids, and hardness from sanitary analyses. That some of the waters may show, when the wells are pumped heavily, a very different composition from that indicated by the table is altogether possible, as the heavy pumping of wells in crystalline rocks may modify the circulation of the water for a considerable distance.

TABLE 3.—Details of Deep Wells in Crystalline Rocks.

County and Place	Owner	Year completed	Elevation of surface	Depth	Diameter of casing	Depth to chief supply	Depth to other supplies	Length of casing	Depth to rock	Water stands below surface	Yield to pump	Temperature	Use	Quality	Remarks
DINWIDDIE: Petersburg	J. B. Worth & Co.....	.....	<i>Ft.</i> 20	<i>Ft.</i> 150	<i>In.</i> 8	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i>	<i>Ft.</i> 5	<i>Ft.</i>	<i>Gal.</i> 50	<i>°F.</i> 59	Ice making		
GREENESVILLE: Emporia	Town	1906	60	600	8	470	370	28	6	10	100	.....	Town supply	Hard, irony	Abandoned
HENRICO: Barton Heights	Town	1909	150	759	8	759	200	.....	115	.....	40	.....	Town supply		
Curle's Neck ...	C. H. Senff.....	1900	26	726	8	357	26	315	311	26	100	.....	Town supply	Soft	
Ginter Park ...	L. Ginter Land & Imp. Co.	1898	200	357	8	.....	.....	.....	123	40	166	.....	Town supply	Hard	
Ginter Park ...	Bloomington Stock Co.....	.....	.....	322	.....	.....	.....	.....	123	.....	25	.....			
Ginter Park ...	"Westbrook" .....	.....	.....	306	.....	.....	.....	.....	96	.....	50	.....			
Ginter Park ...	"Westwood" .....	.....	.....	900	6	.....	.....	.....	108	.....	5	.....			
Ginter Park....	"Westwood" .....	.....	.....	468	6	468	.....	.....	118	.....	50	.....			
Richmond	American Ether Co.....	1900	25	407	6	405	.....	80	117	20	175	.....	Condensing	Salt	Abandoned
Richmond	Albemarle Paper Co.....	1886	10	225	6	.....	.....	200	5	10	25	.....	Drinking, washing		
Richmond	A. D. Atkinson (Richmond Hotel)	1905	157	572	8	.....	.....	196	.....	.....	300	.....	Hotel supply		
Richmond	Chesterfield Apartment Co.	1904	195	365	8	230	.....	.....	.....	150	48	.....	Drinking, boiler		
Richmond	W. S. Forbes.....	1903	180	400	8	.....	.....	.....	.....	.....	300	.....	Boiler and washing		
Richmond	W. S. Forbes.....	.....	180	250	.....	.....	.....	.....	.....	.....	25	.....	Boiler and washing		
Richmond	Home Brewing Co.....	1894	182	550	6	.....	.....	.....	98	125	50	62	Brewing	Hard	
Richmond	Home Brewing Co.....	1899	182	550	8	.....	.....	.....	98	.....	5	.....	Brewing	Hard	
Richmond	Home Brewing Co.....	1899	182	650	8	.....	.....	.....	98	.....	0	.....			Dry hole
Richmond	Jefferson Realty Co.....	1895	180	425	4	410	.....	.....	123	.....	.....	.....			Not used in 1906
Richmond	Jefferson Realty Co.....	1896	180	445	8	425	.....	400	123	60	60	62	Hotel	Soft	
Richmond	Kingan & Co.....	1893	.....	428	6	.....	.....	149	23	20	60	62	Condensing	Corrosive	
Richmond	Kingan & Co.....	.....	180	300	8	.....	.....	.....	.....	.....	.....	.....	General		
Richmond	Murphy Hotel Co.	1904	175	450	8	250	.....	150	125	100	45	.....	Hotel, medicinal		Pumping 50 gal. p. m. lowers water 50 feet.
Richmond	Murphy Hotel Co.	1906	175	702	8	650	.....	169	125	.....	65	.....	Hotel		
Richmond	Merchants Cold Storage & Ice Co.	1901	95	248	8	.....	.....	.....	.....	.....	120	62	Condensing		
Richmond	Richmond Paper Co.....	1884	83	256	6	250	.....	.....	.....	60	20	.....		Irony	Abandoned
Richmond	Richmond Union Stockyards Co.	1899	.....	385	8	.....	.....	180	.....	.....	5	.....	Watering stock		Dry hole
Richmond	Seaboard Air Line	1900	200	500	8	.....	.....	200	.....	.....	0	.....			
Richmond	Southern Stove Works....	1892	.....	300	6	.....	.....	.....	.....	.....	200	.....	Boiler, drinking		
Richmond	Transparent Ice Co.....	1900	105	703	6	.....	.....	47	.....	15	60	.....	Ice making		Plant idle in 1906
Richmond	Virginia State Penitentiary	.....	115	248	6	240	.....	.....	38	.....	150	.....	General		
Richmond	Virginia Union University	.....	.....	200	6	.....	.....	.....	.....	40	70	.....			
School	Laurel Reformatory School	1905	.....	300	8	.....	.....	33	23	25	60	.....	General		

TABLE 4.—*Analyses of well water from crystalline rocks.*

(Parts per 1,000,000)

Locality	Owner	Total solids	Organic and volatile matter	Silica (SiO ₂)	Iron and aluminum oxides (Fe ₂ O ₃ +Al ₂ O ₃)	Iron (Fe)	Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Arsenic (As)
Catman	C. H. Senff	234	12.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ginter Park	Lewis Ginter Land and Improvement Co.	620	6.6	28.0	1.2	.....	.....	.....	55.2	11.0	.....	128.0	8.5	.....	.....
Richmond	American Ether Co.	1610	.....	32.0	16.0	.....	.....	.....	16.0	8.9	.....	380.0	.....	.....	.....
Richmond	Chesterfield Apartments	287	5.9	47.0	.....	0.5	0.5	.17	29.0	12.0	.24	18	3.7	.01	.....
Richmond	Hotel Jefferson	173	.....	38.0	0.5	.....	.....	.....	30.0	8.6	.....	6.2	1.2	.....	.....
Richmond	Home Brewing Co.	448	20.0	.....	.....	tr.	.....	.....	68.0	12.6	.....	.....	.....	.....	.....
Richmond	Kingan & Co.	779	.....	31.5	0.9	.....	.....	.....	68.0	27.0	.....	.....	.....	.....	.....
Richmond	Kingan & Co.	260	58.0	.....	.....	.....	.....	.....	0.8	2.2	.....	74.0	.....	.....	.....
Richmond	Murphy Hotel Co.	196	0.82	34.4	.....	0.31	0.3	.063	21.0	9.5	.1a	21.9	5.9	.015	.....
Richmond	Richmond Hotel	702	.....	28.0	.....	0.18	1.1	.03	68.0	28.0	.....	69.0	28.0	.01	.....
Richmond	Southern Stove Works	319	.....	26.0	.....	0.1	0.3	.....	2.7	0.7	.....	76.0	3.6	tr.	tr.
Richmond	Southern Stove Works	271	28.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Richmond	State Penitentiary	190	20.0	20.0	.....	.....	.....	.....	8.6	0.98	.....	46.0	.....	.....	.....
Richmond	W. S. Forbes	92	8.0	15.0	.....	0.4	.....	.....	4.0	0.2	.....	22.0	.....	.....	.....
Richmond	Virginia Union University	559	207.0	40.0	.....	.....	.....	.....	82.0	12.0	.....	7.6	.....	.....	.....
Sherwood Park	.....	66.7	.....	27.0	2.9	.....	.....	.....	7.0	1.3	.....	.....	.....	.....	.....
School	Laurel Industrial School	392	.....	.....	.....	.....	.....	.....	26.0	8.6	.....	106.0	.....	.....	.....

^aWater also contains .05 parts barium (Ba).^bWater also contains .041 parts barium (Ba).

TABLE 4. (Continued.)—Analyses of well water from crystalline rocks.
(Parts per 1,000,000)

Locality	Owner	Carbonate radicle (CO ₃)	Bicarbonate radicle (HCO ₃)	Sulphate radicle (SO ₄)	Phosphate radicle (PO ₄)	Bromine (Br)	Iodine (I)	Chlorine (Cl)	Nitrate radicle (NO ₃)	Analyst and date
Catman	C. H. Senff.	.....	.....	.....	0.0	.....	.....	37.5	0.0	J. A. Deghuée
Emporia	Lewis Ginter Land and Improve-	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ginter Park	ment Co.	87.0	263.	263.	.....	.....	.....	37.0	0.18	Froehling, 1902
Richmond	American Ether Co.	86.0	93.0	93.0	.....	.....	.....	778.0	.....	Froehling, 1892
Richmond	Chesterfield Apartments	.....	138.0	26.	0.8	tr.	.009	6.1	.....	Froehling & Robertson, 1904
Richmond	Hotel Jefferson	51.0	33.0	33.0	.....	.....	.....	4.5	.....	Froehling, 1896
Richmond	Home Brewing Co.	.....	144.	144.	.....	.....	.....	25.0	0.0	First Scientific Station for the Art of Brewing
Richmond	Kingan & Co.	105.0	.....	105.0	.....	.....	.....	.....	.....	Froehling, 1893
Richmond	Kingan & Co.	.....	.....	105.0	.....	.....	.....	113.0	.....	H. Bentley Smith Co., 1904
Richmond	Murphy Hotel Co.	70.0	24.0	24.0	.19	.....	.002	6.6	0.15	Froehling & Robertson, 1904
Richmond	Richmond Hotel	.....	182.0	282.0	.25	tr.	tr.	63.0	.....	Froehling & Robertson, 1906
Richmond	Southern Stove Works	.....	183.0	17.0	.....	tr.	tr.	8.5	0.8	Froehling, 1902
Richmond	Southern Stove Works	.....	.....	.....	.....	.....	.....	12.0	0.25	H. Bentley Smith Co., 1904
Richmond	State Penitentiary	57.0	12.0	12.0	.....	.....	.....	13.0	.....	Froehling, 1903
Richmond	W. S. Forbes	25.0	12.0	12.0	.....	.....	.....	5.3	.....	.....
Richmond	Virginia Union University	96.0	10.0	10.0	.....	.....	.....	35.4	68.0	H. Bentley Smith Co., 1905
Sherwood	Laurel Industrial School	4.2	.....	.....	.....	.....	.....	.....	.....	Froehling, 1897
School	.....	54.0	101.	101.	.....	.....	.....	96.0	.....	H. Bentley Smith Co., 1907

A comparison of the analyses shows that the total solids range from 66 to 1,600 parts per million; the calcium from 1 to 70 parts; the magnesium from 0.2 to 28 parts; the sodium from 6 to 580 parts; the carbonates and bicarbonates from 4 to 180 parts; the sulphates from 10 to 260 parts; and the chlorine from 4.5 to 780 parts. The differences are explained by differences in the underground circulation.

Changes in quality of the water.—Little can be foretold regarding the bacterial purity of the supplies from wells in granite underlying a densely populated area. Where the surface drainage is good, the soil cover on the rock thick, and the well casing tight, conditions which may obtain at all wells on high ground in Richmond, the danger of contamination is remote. But heavy pumping can produce such changes in the circulation of granite waters that the waters from wells which are seemingly not exposed to contamination may be easily polluted. After being in use a year, a deep well at Atlanta, Ga., was fouled by impure waters that may have entered the well at a depth of several hundred feet. Hence it is advisable to analyze periodically the water of a deep well that is heavily pumped.

At Richmond the joint cracks of the granite may be filled either with river water, with ground water slightly filtered, or with water that has soaked through many feet of stratified material of varying composition. These waters may mingle after a relatively short journey under ground, or after having passed through a long series of intersecting joints and having descended hundreds of feet. A particular well may draw on one crevice or a series of connecting crevices, and hence the quality of the water from nearby wells may differ greatly.

An erratic well water, like that of the American Ether Company, obviously must be local. Various explanations have been suggested for the saline character of somewhat similar waters found in granite. A reasonable explanation for the Richmond area is that sea-water accumulated in crevices at a time when the James was salt as far west as the rapids; an alternative is derivation from water that did not come from the surface but ascended from a great depth in the earth's crust.

DEEP WATERS OF THE NORFOLK-NEWPORT NEWS AREA

General statement.—The possibility of obtaining artesian water by deep drilling near the mouth of the James first attracted attention 65 years ago when Government authorities were looking for something better than cistern or shallow well water for the supply of Fort Monroe. Since then

wells have been drilled near Fort Monroe; on Back River, 7 miles north of the fort; at Newport News, 7 miles west; and in the vicinity of Norfolk, from 8 to 15 miles south and southeast. In all, fully 10 wells have been put down and not one has been considered a complete success. Some did not find flows, some found flows that were too salty for drinking or boiler supply, and some found little water.

Because a great number of successful wells have been drilled elsewhere in Tidewater Virginia, and because drillers and others have claimed that it is possible to get artesian water in the vicinity of Norfolk and Newport News, the questions whether there is a possibility of finding such water and why the wells thus far drilled have been unsuccessful merit detailed answers. Besides, although Norfolk and Newport News had in 1906 good public supplies the number of manufacturing establishments near the mouth of James River that may desire to procure for industrial purposes cheaper water than that furnished by public service systems is large, and some may attempt to find it by deep drilling. As enough work has been done to permit definite answers to some questions that would arise in the mind of any one investigating artesian possibilities, whether well owner or driller, a review of the results of deep work in the Norfolk-Newport News area and what these results indicate may save misdirected effort and wasted money. In fact, the reason for the failures to get good artesian water about Norfolk was the most important problem that came up for investigation in the course of the field work for this report.

Limits of area.—By the term Norfolk-Newport News area is meant Elizabeth City County and the south end of Warwick County, which are north of James River and Hampton Roads, and the north part of Norfolk and Princess Anne counties which lie south and southeast of the mouth of the James. The area is thus defined not because its deep wells show features which are not presented by wells elsewhere, but because of its population (over 75,000) and because it is destined to be of increasing importance as a manufacturing district. As has been indicated in the general discussion of artesian conditions in the Virginia Coastal Plain and as the accounts of work in other counties show, no flows, scanty flows, or highly mineralized water seem to be characteristic of the deep wells (more than 400 feet) in a considerable area, one that probably embraces most of Norfolk, all of Princess Anne County, the east end of Gloucester County, part of Mathews County, the east end of Middlesex County, most of Accomac and all of Northampton County.

DEEP WELLS NORTH OF JAMES RIVER

Fort Monroe.—The first deep boring in the Norfolk-Newport News area, the first in Tidewater Virginia and one of the first in the entire Atlantic Coastal Plain—the first probably being the unsuccessful well at Charleston, S. C., sunk in 1823 to a depth of 335 feet—was begun by the Government in 1864 to obtain a supply to supplant or supplement the cistern water used at the post. A previous attempt, in 1845, had reached a depth of 168 feet. In spite of the great advance in the art of well-drilling between 1845 and 1864, rigs and tools for rapid work in the soft unconsolidated beds of the Coastal Plain had not been devised at the latter date, nor were drillers generally aware of the troubles that await the man who, skilled in drilling rock wells, undertakes with such experience as a guide to sink through clays and quicksands. So it is not surprising that the well was abandoned in 1869 at a depth of 907 feet. The attempt proved of decided value to science, because the samples of the strata penetrated were examined by Rogers^a in 1869 and later by Fontaine and Darton, and the records compiled from this study (which have been published by Darton^b) gave the first information on the total thickness far under cover of the Miocene and Eocene deposits in Virginia. Practically, the well was a failure; several sands containing water under so low a head that it would not rise to surface may have been penetrated, but the only water noted in the record was struck in gray sand at 599 feet. This water had head enough to rise above the level of the parade ground, 3 feet above tide, but was “very saline.”

In the report, dated 1876, by S. T. Abert^c on the survey of a line to connect the waters of the Cape Fear and Neuse rivers and for a connection by water between Norfolk harbor and Cape Fear River appears this record of borings 313 feet deep at Fort Monroe. The object of the work is not stated and no mention is made of water.

^aRogers, W. B., *Geology of the Virginias*, 1885, p. 733.

^bDarton, N. H., *Artesian Water Prospects in the Atlantic Coastal Plain*, U. S. Geol. Survey, Bull. 138, pp. 168-169.

^cU. S. War Dept., 44th Congress, 1st Session, Senate Doc. No. 35, p. 16.

Record of borings at Fort Monroe, Va.

(Authority, U. S. Engineer's Office.)

Materials	Thickness (Feet)	Depth (Feet)
Marsh soil	5½	5½
Fine clean dark sand.....	12½	18
Angular light-colored sand, containing coarse sand, round pebbles and mud	10	28
Sand and mud, different layers.....	12	40
Some stone, sand and mud.....	5	45
Miocene marl	200	245
(The lowest layer of the last showed some greensand and shells, next hard stone full of shells)		
Sand, bluish-gray, mixed with mud.....	16	261
Same, fragments of shell marl, stone harder.....	9	270
Softer marl, sky blue.....	43	313
A note says "fossil shells or continuous marine deposits were 224 feet in thickness."		

A final and decisive attempt to find potable artesian water at Fort Monroe was made in 1902. This well, sunk within the fort, started at an elevation of about 3 feet, passed through all underlying formations of the Coastal Plain, struck crystalline bed rock at 2,240 feet below mean high tide, and was sunk in this rock 8 feet, making its total depth 2,251 feet—the deepest well in the entire Atlantic Coastal Plain from New York to northern Florida. A hydraulic jet rig was used and progress was rapid in spite of the large diameter; 15-inch casing was placed at the start and 12-inch to 1,200 feet; below 1,200 feet the driller had so little trouble that 9-inch casing was used down to 2,128 feet; beyond that depth the well was not cased. Drilling began January 25, and on April 21 the well was down 2,200 feet.

Some samples of borings were saved during the progress of the work and the driller noted the general character of the beds. The type of the rig and possible errors in labelling the samples make the borings of slight determinative value, and the driller's notes are not detailed enough to be of value in discriminating formations. Hence an accurate record of this well is not available.

According to Capt. C. P. Townsley, U. S. A., while boring was in progress nothing could be told about any water bed struck except by casing to it and bailing the well. This was done at 1,317 and 2,128 feet, and at both depths the water was very salty. Evidences of water appeared at 1,520, 1,630, 1,915, and 1,939 feet, but were not tested. The head of the

water at 2,128 feet was 20 feet below surface and the yield was so small that with an 8-inch boiler 21 feet long the water was easily lowered 1,000 feet in the 9-inch casing in 10 hours. The most promising horizons between 1,320 feet and 2,128 feet were at 1,640 feet and 1,915 feet. According to another officer, who happened to be at the fort in 1902 and speaks from memory, the largest flow found had head enough to just run over the casing, elevation about $6\frac{1}{2}$ feet above mean tide. Efforts to develop flows of potable water at points above 2,128 feet by the use of dynamite proved unavailing; in consequence the 12-inch casing down to 600 feet and the 9-inch down to 1,200 feet were removed and no use whatever has been made of this well.

No quantitative analyses of the water from any flow appear to have been made; if any were, there is no record of them.

Newport News.—In 1882, the Old Dominion Land Company which had undertaken extensive real estate developments at Newport News, began a search for artesian water there. Unfortunately drilling began on ground 31 feet above sea level, so that the prospects for a flowing well, as subsequent work has shown, were not bright. Work started March 9, with a standard cable rig. The driller met with many accidents, in repairing some of which he had more than average good luck. At a depth of 329 feet, reached on March 31, it was found impossible to drive the 8-inch casing farther; a series of accidents followed the resumption of work with 6-inch casing, and after this casing had broken in several places, the well was abandoned on July 28, after it had been sunk $582\frac{1}{2}$ feet.

The following log is compiled from the record preserved by the company.

Record of well of Old Dominion Land Co., Newport News, Virginia.

(Authority, Old Dominion Land Co.)

Material	Thickness (Feet)	Depth (Feet)
Sand "6 kinds"	18	18
Sand and yellow clay.....	15	33
Sand and hard tough blue clay	36	69
Hard blue clay containing sand with shells; clay, dark blue but soft, with few shells at 106 feet.....	37	106
Blue clay	19	125
Quicksand	7	132
Greenish sandy clay, or marl, with numerous large shells; hard bluish sand-rock at 184½ to 186 feet; water below rock rose high enough to be seen by looking down pipe.....	121	253
Greenish or bluish clay, free from sand.....	253	270
Hard stiff tough blue clay	69	339
Bluish "soapstone"	70	409
Lighter more sandy clay which "changes" at 414 and 420 feet	14	423
Coarse sand; water rose to within 10 feet of the surface.....	3	426
Shells, stone and sand.....	2	428
Sand, which rose nearly 150 feet in pipe over night.....	9	437
Sand with streaks of cement rock.....	18	455
Sand, clayey towards bottom	38	493
Heavy brownish clay, gravelly towards bottom.....	14	507
Clay with stones	39	546
Clay and sand	36	582

Water was struck at two horizons in the Chesapeake group, namely, below a rock stratum at 186 feet and in a bed of coarse sand at 422 feet; neither horizon was given a good test; the water in the 422-foot bed rose perhaps 21 feet above sea level. It is unfortunate that no note was taken of the quality or volume of this water; it might have yielded a good flow at a lower elevation.

In 1907, H. E. Shimp began a well for the Old Dominion Brewing Co. at Newport News, but stopped work at a depth of about 500 feet. He did not keep a record of the section shown by the drill, and the samples he saved were lost before they could be examined by a geologist.

Back River.—A deep well was sunk in 1886 at the site of a contemplated fish factory on the tip of the sand spit, known as North End Point, on the south side of the entrance to Back River, about 7 miles north-northeast of Fort Monroe. This well reached a depth of 1,172 feet; there the drill struck a very hard stratum, which the driller thought was granite; the drill rod broke and work was abandoned. The notable thing about this well is

that no water worthy of mention was found except in two beds of gravel, between 1,000 and 1,007 feet, in the Potomac group. Whether water in sufficient quantity might have been found by properly testing some of the sandy beds penetrated is uncertain. Darton has published the following record.^a

Record of well at North End Point.

(Authority, C. C. Knox)

Material	Thickness (Feet)	Depth (Feet)
White sand and gravel	75	75
Blue clay	5	80
White sand	20	100
Thin layers of sand and blue clay	30	130
Blue or gray sand	25	155
Quicksand	10	165
Hard white sand	5	170
Loose white sand	15	185
Black marl	12	187
White sand and marl	162	249
Rock	1	250
Blue clay	17	267
Stone	1	268
Hard sand	7	275
Blue clay with thin marl layers	55	530
Hard blue clay	70	600
Quicksand	18	618
Stone or boulder	2	620
White sand	5	625
Yellow sand	1	626
Clay and sand mixed	29	695
Gravel and clay	1	696
Hard and soft layers of blue clay	4	740
Very hard clay	8	748
Soft blue clay	165	913
Hard blue clay	7	920
Coarse sand	6	926
Sandstone	3	939
Hard sandstone	16	955
Hard sand with few gravels	18	973
Hard sandstone	27	1000
Sandstone with two veins of gravel and some water	7	1007
Alternate layers of sand and sandstone 3 to 4 feet thick	8	1015
Alternate layers of sand and sandstone 3 to 15 feet thick	65	1080
Very hard white sand	80	1100
Sandstone	155	1155
Red sandstone	5	1160
Hard sandstone	10	1170
Hardest kind of stone or granite; here drill rods broke and work was abandoned	2	1172

^aDarton, N. H., Artesian Well Prospects in the Atlantic Coastal Plain, U. S. Geol. Survey, Bull. 138, pp. 171-172.

Another attempt to get water on North End Point was made in 1896. R. H. Milligan, the driller, used a hollow-rod, jet outfit and had little difficulty in sinking a 3-inch hole 1,035 feet. No water that would flow at surface was found, but in conversation with the writer Mr. Milligan has stated that he thinks, in the light of his experience with deep wells at other points near the shore of Chesapeake Bay, that there are at the mouth of Back River deep-lying sands which will yield flows to a well sunk with regard to the local conditions. Though this is not impossible, the writer is inclined to regard the prospects for obtaining a good flow of potable water from depths below 500 feet at North End Point as distinctly unfavorable.

Hotel Chamberlain.—After the unsuccessful attempt in 1864-69 no further efforts to get artesian water in the vicinity of Fort Monroe appear to have been made until 1896, when a well was sunk at the Hotel Chamberlain. The well started at an elevation of 4 feet above high water, on made ground near the sea wall in the rear of the hotel, and reached a depth of 945 feet.

The following record of the well compiled from a study of the borings and notes furnished by the contractor and his foreman has been published.^a

^aWoolman, Lewis, Artesian Wells, Geol. Survey, N. J., Ann. Rept. 1898, pp. 122-125.

Record of artesian well at Chamberlain Hotel, Old Point Comfort.

Material	Thickness (Feet)	Depth (Feet)
Surface sand	10	10
Sand with minute fragments of shells	20	30
Dark gray sand, spines of sea urchins plentiful.....	10	40
Sand, lighter in color	10	50
Sandy clay with Miocene shells.....	10	60
Greenish sandy clay	30	90
Sandy clay with Miocene shells.....	10	100
Greenish sandy clay, a few shells	20	120
Greenish sandy clay, with shells in great number.....	10	130
Fine dark gray sand, sea urchins spines abundant.....	30	160
Dark brownish sandy clay, with shells.....	20	180
Dark greenish clay (marine shells, Miocene age, at 190, 200, 270 feet)	100	280
Dark greenish clay, more sandy, but without shells.....	60	340
Dark greenish clay, not so sandy, still without shells.....	190	530
Dark bluish-green diatomaceous clay	30	560
Dark clay, not diatomaceous	30	590
Dark brownish sandy clay.....	20	610
Greenish clayey sand, with a large admixture of greensand grains and some foraminifera.....	50	660
Greenish sandy clay with green sand and foraminifera.....	50	710
Brownish sandy clay	710	800
Gray sand, mixture of greensand grains and pure quartz grains	20	820
Brownish clayey sand, also contains a mixture of greensand and quartz grains	20	840
Calcareous rock crust and pebble conglomerate with some wood and shells	10	850
Dark sandy micaceous clay	55	905
Fine gray sand	15	920
Coarse gravel, water-bearing	25	945

The well gives a rather small flow, inasmuch as the inner casing is 4 inches in diameter, of the saltiest and most mineralized water yielded by any flowing well in the Norfolk-Newport News area. Though the log makes no mention of water above 945 feet, it is likely that several sandy beds were penetrated which contained water under insufficient head to flow at surface. The driller gave the estimated yield as 50 gallons per minute^a and the head as over 17 feet above surface or about 22 feet above sea level. In 1906, according to the engineer of the hotel power plant, the flow, at surface, was "a 3/4-inch pipe full" and the head was 14 feet above tide. The flow at 5 feet elevation is certainly not over 25 gallons per minute. The water has so much mineral matter in solution that it is not used except for flushing; it is too salty for drinking or for boiler use and is so

^aDarton, N. H., U. S. Geol. Survey, Folio No. 80, 1902.

iron-bearing that, though perfectly clear when fresh from the well, it soon becomes turbid and deposits much ferric hydrate. Hence it is unsuitable for bathing or for laundry use.

The following analysis made in March, 1906, shows that though highly mineralized, the flow resembles the excellent water from artesian wells to the west in containing much soda and comparatively little lime or magnesia, in proportion to the total solids. Much of the increased mineralization is probably in the form of common salt, sulphates of soda, potash, lime, and magnesia, and iron compounds.

Analysis of water from 945-foot well at Hotel Chamberlain, Fort Monroe.
(W. H. Taylor, analyst.)

	Parts per 1,000,000
Total solids	9248
Silica (SiO ₂)	14
Aluminum (Al)	23
Iron (Fe)	16
Calcium (Ca)	97
Magnesium (Mg)	44
Sodium (Na)	3268
Potassium (K)	87
Lithium (Li)	trace
Bicarbonate radicle (HCO ₃)	433
Sulphate radicle (SO ₄)	265
Chlorine (Cl)	4978

The following sanitary analysis, also made in March 1906, shows some additional characteristics of this water:

Sanitary analysis of water from 945-foot well at Hotel Chamberlain.
(Penniman and Brown, analysts.)

	Parts per 1,000,000
Total solids at 200° F.	9145.
Volatile solids	188.
Chlorine	4940.
Nitrogen as free ammonia	1.50
Nitrogen as albumenoid ammonia	0.16
Nitrates	trace
Nitrites	none

DEEP WELLS SOUTH OF JAMES RIVER

General statement.—In that part of the Norfolk-Newport News area south of James River and Hampton Roads, at least six wells over 200 feet deep have been sunk, but detailed records of only two are available.

However, the results of the borings are sufficient to determine the prospects for getting potable artesian water from deeply buried beds. As will be seen, though no waters are known to have been found as highly mineralized as the flows tapped by the borings near Fort Monroe, particularly the Hotel Chamberlain well, the flows all contain large amounts of solids in solution, are not what would ordinarily be called good potable water, and are not suited for boiler supply.

Virginia Beach.—One of the earlier borings for deep water in the southern part of the area under discussion was made in the winter of 1888-1889 at the Princess Anne Hotel at Virginia Beach. The elevation of the surface was possibly 7 feet. According to F. O. Clebourne, who was at the time in the employ of the company that had the work done, the well was sunk 600 feet and found no water below 73 feet. No record of the beds penetrated was kept, nor is any information available to show whether possible water-bearing beds were properly tested, but it is probable that no bed which would have yielded a flow was penetrated.

Masons Creek.—George S. Bunting states that in 1890, using a hand rig, he drilled a 1½-inch well 575 feet deep near Masons Creek, a short distance west of the present post-office of Rixton. Mr. Bunting kept no record but remembers that he cased the well to 260 feet and drilled from there to the bottom without casing. At some point below 260 feet, he struck a weak stream which did not give a flow though the elevation of the surface is not over 10 feet. A bed of shells was struck at 200 feet and shell beds or hard layers were struck at 160, 252, and 500 feet, but from 260 to 575 feet nearly all the material was fine, bluish sand.

Money Point.—South of Norfolk, on Elizabeth River, at Money Point, two deep wells were bored, but no record of either seems to have been preserved. One well has been long abandoned; the other, 562 feet deep, is said to flow 30 gallons per minute of brackish irony water at an elevation of 5 feet above tide. The flow is not suited for boiler use but is reported to be drunk as a mineral water by some people in the vicinity of the well.

Lambert Point.—In 1891 a well was completed near the pier at the Norfolk and Western Railroad terminal on Lambert Point, north of Norfolk. The well, which is close to the shore and was drilled for boiler supply, reached a reported depth of 616 feet. It struck a strong flow, 65 gallons per minute, at 610 feet in a coarse micaceous sand; and a weak flow, about 1 gallon per minute, at 603 feet in another sand bed. The

driller kept a record and saved samples. Records compiled from an examination of the samples have been published by Darton^a and by Woolman.^b The following log is given in slightly different form.

Log of well on Lambert Point.

Material	Thickness (Feet)	Depth (Feet)
Slightly yellowish sand, shell fragments.....	17	17
Bluish clay, shell fragments	27	44
Gray, fine micaceous sand, shell fragments.....	139	183
Greenish gray, sandy clay	8	191
Gray micaceous sands	42	233
Greenish gray fine sand and clay; tough when dry (fossil shells)	31	264
Gray or bluish clay	22	286
Gray or bluish fine sand, shell fragments.....	69	355
Gray or bluish clay	22	377
Gray, fine sand, shell fragments.....	20	397
Dark gray or bluish clay	10	407
Gray moderately coarse sand, some glauconite.....	19	526
Small gravel, shell fragments.....	8	534
Gray or bluish clay	23	563
Rock, shell fragments	1	564
Dark hard fine micaceous sandy clay, well laminated.....	4	568
Rocky strata with thin layers of clay and shell fragments.....	35	603
Small gravel in gray sand, shell fragments, water.....	3	606
Rock, shell fragments	4	610
Gray, fine to moderately coarse micaceous sand, oyster shells	6	616

In the Norfolk folio of the U. S. Geological Survey Darton gives a list of shells and diatoms found in the borings. These show the water-bearing sand to be of Upper Cretaceous (Matawan) age.

The flow from the 610-foot sand was, when tested in 1898, 65 gallons per minute through the 6-inch casing at an elevation of 7 feet above surface, or 15 feet above mean high tide; the head was about 30 feet above sea level. Tests in 1906 showed that the well was yielding 51 gallons per minute. The temperature of the flow is 72° F.

The water is drunk by some employees at the terminal and by many people in the vicinity, but while it undoubtedly has medicinal value it is rather too mineralized for steady drinking. The prime reason for classing the well as unsuccessful, however, is that the railroad company has made little use of it except for washing cars and cleaning up around the piers. In a boiler the water foams badly and rapidly corrodes stay bolts. It

^aDarton, N. H., Op. cit. p. 172.

^bWoolman, Lewis, Ann. Rept. N. J. Geol. Survey, 1899, pp. 87-92.

probably contains considerable common salt and bicarbonate of soda (though no bicarbonates are reported) and some sulphate of soda. It contains very little lime. The following analysis was made in 1891:

*Analysis of water from 616-foot well of Norfolk and Western Railroad,
Lambert Point.*

(C. W. Shepard, analyst.)

	Parts per 1,000,000
Total solids	1093.
Silica (SiO_2)	10.
Oxides of iron and alumina ($\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$)	0.91
Calcium (Ca)	5.0
Magnesium (Mg)	1.7
Sodium (Na)	415.
Potassium (K)	21.
Sulphate radicle (SO_4)	43.
Carbonate radicle (CO_3)	245.
Chlorine (Cl)	351.

Whether better water could have been had by deeper drilling is doubtful. It is barely possible that water a little less mineralized might have been found above 1,000 feet; below that depth, judging from the results of other borings, it is likely that the water obtained would have been more saline.

Moore's Bridges.—A well was sunk at Moore's Bridges, 5 miles north-east of Norfolk near Diamond Springs post-office, by the Norfolk City Water Department in 1890, to a depth of 730 feet; it found salty water. The next and the most important well in the southern part of the Norfolk-Newport News area was sunk in 1896-98 at Moore's Bridges, to test all the water-bearing sands found down to bed rock. A standard cable rig was used. Partly on account of the rig, work progressed slowly, and operations were finally abandoned at 1,760 feet below surface, elevation about 8 feet above sea level.

The following log has been slightly changed from the form in which it was published by Woolman^a. References to the microscopic organisms noted by Woolman are omitted.

^aWoolman, Lewis, Ann. Rept. N. J. Geol. Survey, 1899, pp. 92-102.

Record of Norfolk City Well near Waterway.

Material	Thickness (Feet)	Depth (Feet)
Light buff sandy loam.....	3	5
Fine light sand	13	18
Sand, water-bearing	3	21
Bluish clay, fossiliferous	44	65
Bluish clay, not fossiliferous; small streak of gravel at 80 feet	20	85
Gray clayey sand and gravel; scallop shell (Miocene), at 105 feet	20	105
Gray clayey sand, fossiliferous and containing rather large white quartz pebbles at 110 to 115 feet. <i>Rangia cuneata</i> shell at 125 feet	20	125
Gray clayey sand, with comminuted shell.....	40	165
Fine bluish clay, scallop shell (Miocene) at 185 feet.....	85	250
Gray clay, with much sand; full of shells about 5 inches long, boring had to be cased	10	260
Dark greenish sandy clay.....	25	285
Soft clay which ran into boring.....	20	305
Greenish gray clay.....	5	310
Gray sandy clay, very sandy clay had to be cased off, 310-320 feet	65	375
Light fine less sandy clay.....	70	445
Light gray fine clay, comminuted shell at 465-475 feet.....	135	580
Slightly lighter, fine clay, called "brown mud" by driller.....	45	625
Green sand marl (glauconite) mixed with white quartz sand..	10	635
Dark greenish clay	30	665
Dark sticky hard clay	20	685
Gray sticky hard clay, with glauconite described by driller as "sand gravel and marl"	20	705
Lighter gray sticky fine clay; much comminuted shell at 715 feet	23	728
Gray sand, small flow of salty water.....	2	730
Soft sandy clay, with much comminuted shell.....	5	735
Small gravel (and clay), flow of salty water.....	10	745
Very sandy greenish clay, micaceous sand, fossil shell Upper Cretaceous at 755 feet to 765 feet; water at 740 to 750 feet	20	765
Gray micaceous sand with a little glauconite; flow of water at 780 to 783 feet Upper Cretaceous shell.....	18	783
White, very light gray, sticky clay.....	2	785
Gray quartzose sand, some mica, no glauconite; slightly salty water, flow 35 gallons per minute at surface, 786 to 805 feet	30	815
Decidedly darker gray sand, no glauconite.....	20	835
Lighter gray sand	35	870
Gray very sandy clay	20	890
Black sticky mud (no sample)	8	898
Clayey sands or alterations of gray sands and clays, sands micaceous; lignite at 925 and 965 feet, quartz pebbles at 925-935 feet; slightly salt water; flow 75 gallons per minute at 950 feet; 10 gallons per minute at 975 to 980 feet; 15 gallons per minute at 985 feet.....	93	991

^aAll sands between 750 and 783 feet are said to have flowed into the well. This indicates the sands were loose, but not, as Woolman suggests, strongly water-bearing.

Record of Norfolk City Well near Waterway—(Continued).

Material	Thickness (Feet)	Depth (Feet)
Slightly yellowish (greenish when fresh) sandy clay.....	42	1.033
Gray sands, some micaceous, pebbles at 1,060-1,070 feet; flows of salt water, 25 gallons at 1,038 feet; 150 gallons at 1,070 feet	45	1.078
Gray sands, clayey and micaceous above 1,100 feet	32	1.120
Darker gray fine to coarse sands, heavy pebbles at 1.130 feet; coarse gray sand lignite at 1,160 feet; heavy pebbles and water at 1,190 feet, yield of water by bailing 350,000 gallons per 24 hours; said to have been fresh at first, afterwards salty	30	1.190
Reddish and reddish yellow or buff clays and clayey sands, heavy pebbles at 1,210 feet.....	40	1.230
Dark fine clay and micaceous sand (?) called "black marl" by driller but not a greensand (glaucanite) marl; lignite at 1,250 feet	25	1.255
Slightly yellowish-olive somewhat micaceous sand; "some water"	35	1.290
"White marl" (no sample)	5	1.295
Reddish yellow and gray clays and sandy clays called "red marl," but not glauconite; fossil shell (Upper Cretaceous) reported from 1,320 feet.....	35	1.330
Alternations of sands (micaceous 1,320-1,340 feet; not micaceous below) and clayey sands varying from white or light gray to yellowish in color; heavy pebbles at 1,470-1,480 feet and 1,540-1,570 feet. Clay beds (no samples), 1,356-1,358 feet; 1,400 to 1,410 feet; 1,557-1,560 feet; 1,568-1,571 feet; lignite at 1,500 feet; salt water, good flow at 1,480 feet; flows at 1,510-1,517 and at 1,535 feet.....	250	1.580
Dark slightly variegated clay.....	20	1.600
Reddish or slightly reddish coarse sands and clayey sands; beds of clay (no samples) probably not glauconitic but bluish when wet, at 1,640-1,647 feet; 1,650-1,654 feet; 1,677- 1,680 feet	80	1.680
Dark coarse very sandy clay, slightly variegated with red, similar to that from 1,580-1,600 feet, but more sandy; probably dark clay beds at 1,683-1,685 feet and 1,693- 1,695 feet	20	1.700
Reddish variegated clay	42	1.742
Loose sand which ran up 150 feet in casing; evidently water- bearing (no sample)	20	1.762

Darton^a states that water beds were found at 783, 805, 950, 975, 984, 1,038, 1,072, 1,190, 1,220, 1,227, and 1,480 feet, and at the bottom, which yielded from 10 to 150 gallons per minute under the pump. One or two of the beds may have given more but no flow of fresh water was struck. The water from the 1,190-foot bed did not quite overflow; at 1,220, 1,227, and several points below small volumes of salt water were found, and at

^aDarton, N. H., Geologic Atlas of United States, Norfolk Folio, No. 80, p. 4.

1,480 feet a large volume of very salt water. Twelve-inch casing was used to 778 feet, 10-inch to 1,208 feet, 8-inch to 1,539 feet, 6-inch to 1,730 feet, and 4½-inch to 1,750 feet.

The well was dynamited at 1,072 feet and possibly at other points, and nothing definite is known of the source of the present flow. It is supposed to come from about 680 feet but the temperature indicates a greater depth. The yield amounts to 75 gallons per minute through a 4½-inch pipe, the well mouth being 11 feet above tide. The flow, said to have a head of 20 feet, has a temperature of 76° and a decided sulphur odor, is saline and contains sodium bicarbonate as shown by the following field assay made by the writer in November, 1906.

Field assay of water from deep well at Norfolk City pumping station.

	Parts per 1,000,000
Iron (Fe)	trace
Calcium (Ca)	little
Chlorine (Cl)	1,000.
Bicarbonate radicle (HCO ₃)	620.
Sulphates, as SO ₄	110.
Total hardness, as CaCO ₃	7.5

A sample collected in November, 1904, and analyzed by Dr. Sheperd, city bacteriologist of Norfolk, contained 920 parts of chlorine per 1,000,000.

Had the well been sunk deeper, even to bed rock, the probabilities are that all water found would have been more saline than that struck at 1,072 feet. In fact salinity apparently increased with depth. The sodium chloride content for three flows, from partial analyses made while drilling was in progress, as given by Darton in the Norfolk folio of the Geologic Atlas of the United States, compare thus:

Sodium chloride and total solids in deep waters from Norfolk City well.

(Henry Froehling, analyst)

Parts per 1,000,000

Flow	Total mineral matter	Sodium chloride
730 feet	2,578	1,926
1,038 "	3,345	2,723
1,070 "	3,652	2,830

In 1906 the flow ran into the clear water basin at the pumping station. There is of course not the slightest possibility of the well water being polluted.

COMPARISON OF RECORDS.

The scanty observations recorded by some drillers and the varying terms used in describing what were probably similar deposits makes correlation of the well records difficult. Samples saved from the wells at Fort Monroe, Moore's Bridges and Lambert Point were examined by Woolman and by Darton and the records prepared by them were based largely on the samples. The best series were from the Hotel Chamberlain and Norfolk City wells. In all except the Norfolk City well water-bearing beds may have been passed which were not noted by the driller.

A comparison of the records shows that the Chesapeake group in the Norfolk-Newport News area, considering its thickness, is very poor in water-bearing beds. There is one midway in it at the last well at Fort Monroe, one at the base in the old well, and one near the base at the Money Point well. The Pamunkey is thin and unimportant. Water was found near the top in the last Fort Monroe well and probably at Newport News. Upper Cretaceous beds proved prolific water carriers at the Hotel Chamberlain, Fort Monroe (1902), Lambert Point, and the Norfolk City wells. The Potomac group at Fort Monroe was fully 900 feet thick, and contained many water beds.

The least mineralized water found below 200 feet by any well is the Lambert Point flow, which according to the 1891 analysis contained 1,091 parts per million of total solids of which 518 parts per million, according to a hypothetical combination given by the analyst, were sodium chloride. In comparison, the 738-foot flow of the Norfolk City well, which is presumably from the same group of beds though not necessarily from the same horizon, contained 1,923 parts per million of sodium chloride. Here is a decided increase of salinity in a distance of 10 miles eastward, a fact in harmony with the general increase of mineralization of deep waters toward the ocean, elsewhere noted. The Lambert Point well is the farthest west of the wells in the Norfolk-Newport News area south of James River, its water is least mineralized and comes from the Upper Cretaceous at a depth of only 616 feet. These details are important.

The results obtained from the work here noticed indicate that it is altogether probable that waters found between 500 and 700 feet at Newport News will be less saline than those from beds of corresponding age at Fort Monroe and in character will approach the Lambert Point flow. North of James River the best chances for finding flows of potable artesian water near Newport News are at elevations less than 20 feet and at points

west of a north and south line running through that city; eastward, probabilities rapidly become unfavorable and in the eastern part of Elizabeth City County deep drilling will probably prove a waste of time and money.

South of James River the best prospects are west of a north-north-west line through Lambert Point with diminishing chances of success eastward. In Princess Anne County efforts to get good water by deep boring will, in all probability, be of no avail, and within the city limits of Norfolk there are small chances of getting water better than the Lambert Point flow at depths below 500 feet.

CAUSES OF MINERALIZATION.

The Norfolk-Newport News area, as previously stated, is not exceptional in the character of its deep waters. In fact it forms part of a much larger area which may include the whole Eastern Shore of Virginia and certainly extends south and east into northeastern North Carolina. The possible causes of the high mineralization, saltiness, and other characteristics of the deep waters of this large area will not be discussed here. It is enough to say that the saltiness is not due to sea waters included in the beds when first deposited, since the flows do not resemble sea water in composition, and there are salt flows from Potomac formations, which are not marine. The increased mineralization probably results from several causes. One is difficult circulation due to the decreased permeability of the water beds down the dip; for horizons which yield bountiful flows farther west are not water-bearing in this area and at some localities, as at Back River, water-bearing beds seem to be lacking through 1,000 feet of strata. At the same time, since coarse sands yielding free flows, under good heads, of water too saline for boiler use have been encountered, the texture of the beds can not be the sole factor. Besides increased fineness of sediments, or pinching out of water beds locally or to seaward (causing slow circulation and ponded water), the more effective factors have been long confinement under pressure and, particularly, the invasion of salt water from up the dip in times when the coast was depressed below its present level. Corresponding beds to the west have been more flushed by downward percolating rain water since the last elevation, hence now contain relatively fresh water.

FRESHENING OF DEEP WATER.

That wells which yield saline water may, by heavy pumping or unrestricted flow, come to yield fresh water is a possibility that has attracted

the attention of geologists. Instances of freshening have been reported but whether or not the improvement was due to the replacement of the contained salt water in the water bed by fresh water from up the dip can not always be determined from the evidence available. Fuller^a noted some instances of a change from salt to fresh water in wells near the mouth of Cape Fear River, N. C., and concluded that the freshening represents such a replacement.

In objection to this view it may be said that a well might penetrate a bed containing salt water and one containing fresh. In such a well the yield of the water beds, the heads of the water they contain, the tightness of the well casing, and the possible clogging of the well at one horizon by sand, are factors that would determine the quality of the water obtained.

Permanent freshening with no marked decrease in flow has not been observed, so far as known at any well in the Norfolk area, but it is possible that there has been a very slight decrease in the mineralization of the water from the Lambert Point well, though analyses extending over a period of 18 years, during which time the well has flowed without restraint, show little betterment. A marked decrease in mineralization and in volume of flow was noted in June, 1909, but after the flow was restored by cleaning out the well its quality was substantially the same as before. The important determinations, total solids and chlorine, are given below:

Variations in mineralization of water from Lambert Point well.

(Parts per 1,000,000.)

Date	Total solids	Chlorine
1891	1,091	350
1906, Dec. 15.....	1,421	290
1909, June 17.....	86	23
1909, July 6.....	1,128	290

The freshening of the water in June, 1909, was evidently due to the main flow being cut off or greatly reduced by sand; the quality of the water as shown by the analysis dated June 17, given in table 10, is not at all like that of any deep well in the Norfolk-Newport News area, but resembles that from wells less than 200 feet deep. There was evidently no detectable change in chlorine content between 1906 and 1909; the indicated change between 1891 and 1906 rests on a single analysis, and is not large enough to be entitled to much consideration. Making

^aFuller, M. L., Instances of Improvement of Water in Wells, U. S. Geol. Survey, Water Supply Paper, 160, pp. 96-99.

allowances for differences in analytical methods and in statements of results by different chemists, the variation in chlorine content between 1891 and 1909 is so small that one may fairly assume that it would not pay to drill a well to a known salt-water horizon in the Norfolk-Newport News area in the hope that by unrestricted flow the water would become fresh enough for boiler use.

SUMMARY.

(1). In the Norfolk-Newport News area the prospects for obtaining good boiler water by deep drilling are poor.

(2). The chances of obtaining such water improve west of Newport News and Elizabeth River.

(3). Mineralization increases toward the east and with depth.

(4). Better water is found above 1,000 feet than below.

(5). The high mineralization of the deep waters has been caused by factors affecting a large extent of country.

(6). A flow of salty water may become fresher by allowing the water to run without hindrance, but in this area the decrease in salinity is too gradual to be worth consideration in determining the sinking of a deep well as a business venture.

UNDERGROUND WATER SUPPLIES BY COUNTIES

ACCOMAC COUNTY

General description.—Accomac is the larger of the two counties covering the Virginia portion of what has long been known as the Eastern Shore, the peninsula between Chesapeake Bay and Atlantic Ocean. The county is about 45 miles long by 15 wide and has an area of 478 square miles. Although in 1900 but two counties in the state had a larger population per square mile, there was not within the county in that year a settlement with a population of over 1,000 people. The two incorporated towns, Onancock and Bellehaven, had populations of 938 and 331.

The surface has slight relief and is monotonously level. Except in some small areas, elevations are below 25 feet, hence the surface is mostly part of the Talbot terrace.^a

There are few fresh water streams of any size or even stream valleys. Along the ocean side and on many stretches of the bay side are wide expanses of salt marsh or land flooded at high spring tides. The ocean side is characterized by many off-shore sandy islands of the barrier beach type, of which Chincoteague is the most important. Back of these islands are shallow bays where miles of mud or sand flats lie bare at low tide.

The surface soil, a light warm sandy loam, is in many places underlain by from 2 to 6 feet of buff or light-brown sandy clay and this in turn by a varying thickness of coarse white, gray, yellowish or occasionally brownish sand that contains scattered lenses of gravel and thin beds of light-colored clay with darker beds below.

UNDERGROUND WATERS

Distribution and quality.—The Eastern Shore term for a water-bearing horizon is a spring, and drillers speak of the first, second, third, and fourth "springs" found at such and such depths; the "first spring" being at the water table. The fluctuations of the water table from rainfall are spoken of as the rise and fall of the "springs" and on Chincoteague Island one is told that "the water springs" (stands higher) in shallow wells after wet weather. The "first spring" is in the yellow Columbia sands. As a rule, the second, third and fourth "springs" are in the beds that underlie

^aThe author believes that the terrace here termed the Talbot is in large part to be correlated with the Pamlico of North Carolina.

the yellowish or reddish beds of the Columbia, though in places the second "spring" is the sand and gravel at the base of the light or bright-colored beds, separated from the first "spring" by clays or loams yielding little or no water to a driven well.

The first "spring," the water not being confined, affords no flowing wells, though shallow dug wells in hollows may be full to overflowing after prolonged rains. The "springs" below, the water being confined under relatively impervious beds of clay yield in many places flowing wells at low elevations.

The quality of the underground water varies. Nearness to inlets from the sea or bay is an important factor in the quality of supplies. In general, the water from dug wells or from pumps driven to the first "spring" does not contain as much lime or magnesia as that from the second or third spring; it is also less alkaline. On the other hand, it is rather more likely to be iron-bearing. Probably the best water for general use comes from 50 feet or more below surface. Along the coast and on the islands many shallow wells yield brackish water and many are salted by unusually high tides. Wells 25 to 200 feet on small islands are more apt to yield brackish water than those on the mainland.

Springs.—There are no true springs of commercial importance. In places water seeps from the creek banks at points where the water table curves down to the creek; such springs often disappear in dry weather. There are, however, springs of perennial flow and a few are used for household supply. What is said to be the largest spring in the county flows from the foot of a bluff on the shore of Chincoteague Bay, 2 miles north of Sinnickson. Another spring at Drummonds Mill, near Grape post-office, was once of local repute because its iron-bearing waters were believed to have medicinal value.

Wells.—The commonest type of well is a shallow hole dug to the "first spring." The deepest dug wells are near Assawoman, where some go 40 feet to water, but the depth of the average dug well in the county is about 10 feet. Buckets with chain or rope, or windlass or pulley, lift the water from the well. Here and there are wells with the old-time sweep and bucket. The perishable nature of wood casing and the many sanitary objections to it have led to the introduction of tile, 20 to 24 inches in diameter. The labor cost of digging a well varies according to the depth to water, but seldom exceeds \$5.

Driven wells or "pumps" as they are called, are easily sunk, much used, and give satisfaction. Wells to the "first spring" are often put

down by the owner, a piece of 1½-inch or 2-inch pipe with a pointed cap being driven by a maul; if the clay subsoil is tough, a hole may be bored through it with an earth auger. Many wells over 20 feet deep are sunk by the jet process, as are nearly all wells over 50 feet deep. Most drillers use hand-power rigs, though the driller who has done the most work in the county has a small gasoline engine. Probably no county in Tidewater Virginia has more driven or drilled wells 50 to 100 feet deep. Their usual diameter is 1½ to 2 inches. For such wells hand-power pumps, either iron pitcher pumps, wood pumps, or force pumps, are generally employed, though many residences have wind mills. One driller in 1906 gave the following as his usual charges for putting down driven wells, or, as it is called, "cutting pumps."

10-foot well	{	pitcher pump	.....	\$8
		wood pump	.....	\$12
30-foot well	{	wood pump	.....	\$20
		force pump	.....	\$22
50-foot well	{	wood pump	.....	\$30
		force pump	.....	\$32
100-foot well, no pump, about.....				\$75

This driller has sunk a 103-foot well and finished it with a pitcher pump for \$50. It is usually understood that the owner will furnish free such extra labor as a driller may need.

LOCAL SUPPLIES

New Church.—At this village near the northern line of the county, dug or driven wells to the "first spring" average 12 to 15 feet deep. The water is generally hard. In some wells it is so iron-bearing that it is not fit for laundry use, while in others it contains little iron. The "second spring" from 30 to 35 feet, is also decidedly iron-bearing in most wells. The "third spring" has been developed by two wells, both of which yield excellent water. One of these, owned by J. E. Johnson, is 125 feet deep and draws on water in a bed of shells in dark bluish sand; this water rises to within 4 feet of surface. An ordinary pitcher pump easily supplies 8 gallons per minute. The record of the beds penetrated is as follows:

Record of well of J. E. Johnson, near post-office at New Church.

(Authority, I. B. Clark, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Pipe clay (light gray clay)	7	8
Yellow sand, small pebbles and gravel with plenty of water of poor quality, "first spring"	6	14
Blue mud	30	44
Sand, a little water, "second spring"	3	47
Blue mud	73	120
Dark, bluish sand with small shells, excellent water, "third spring"	5	125

The owner has at his saw-mill nearby a well to the "second spring" which yields a fair boiler water, and a well to the "first spring" at his store. Results of field tests of samples from a 12-foot driven pump and the 135-foot well at J. E. Johnson's store, and the 34-foot well at the mill, made by H. N. Parker, are given in table 7, to show how great are local variations in quality.

The tank of the New York, Philadelphia & Norfolk Railroad is supplied by a pump drawing from eight 2-inch points driven 30 feet, or to the "second spring." These yield fairly good boiler water.

Franklin City and Greenbackville.— These villages are on or near a strip of salt marsh bordering Chincoteague Bay. At Franklin City there are no dug wells as the town site is inundated at high tides. Pumps to the "first spring" yield brackish water. Fairly good water, which rises to mean high tide level, is obtained by driving 30 to 70 feet.

At Greenbackville, where fresh water is found at 6 feet and even less, pumps are driven 10 to 45 feet and obtain water of varying quality. That from some wells is high in iron, lime, and chlorine; that from others is less mineralized. The water tank of the New York, Philadelphia & Norfolk Railroad is supplied by three driven wells 25 feet in depth, which are said to yield a sufficient supply of satisfactory boiler water. At a canning factory nearby, water is obtained by wells driven 15 feet. One well was driven 80 feet but obtained no water below 50 feet. In the thickly settled portion of the village the "first spring" at 5 to 15 feet, supplies most pumps, but is regarded by local physicians with suspicion on account of possible pollution from stables and privies; much of the water obtained at 10 to 12 feet is iron-bearing and brackish. According to T. F. Mumford, who has driven many wells, excellent water is obtained from some wells

not over 40 feet deep, while others yield water containing considerable quantities of mineral salts, chiefly composed of lime, iron, and sodium.

Dr. H. C. Mallory gave the writer samples of residue obtained by evaporating water from three wells at Greenbackville: Those of Elihu Tull, 18 feet; James Chapman, 22 feet; and J. T. Sharpley, 45 feet. These were qualitatively analyzed by R. B. Dole, assistant engineer of the Water Resources Branch of the U. S. Geological Survey, with the following results:

Analyses of residue from well waters at Greenbackville, Va.

	E. Tull	J. Chapman	J. T. Sharpley
Silica	high	moderate	moderate
Iron	high	moderate	low
Calcium	high	moderate	low
Magnesium	high	low	low
Sodium	moderate	moderate	trace
Potassium	low	low	moderate
Sulphates	moderate	low	low

Field tests of samples from the wells of Elihu Tull (18 feet) and J. T. Sharpley (45 feet) at Greenbackville, and James Chapman at Franklin City, showed notable variations in mineralization. (See table 7.)

Drillers charge about \$25 for a 40-foot well and \$35 to \$70 for a 70-foot well.

Chincoteague.—Chincoteague Island and its larger neighbor, Assateague, are growing in popularity as summer resorts and are known to many sportsmen for the duck-shooting on Chincoteague Bay and its connected inlets. The village of Chincoteague has a summer population of over 1,500, and the question of water supply is of increasing importance. Both islands are low and sandy—a succession of beach ridges under 10 feet high, except for a few small dunes that may rise above 15 feet. On Chincoteague water is obtained from dug and driven wells 3 to 14 feet deep, the best water being found in white sand in the higher parts of the island. Only two attempts to find water at greater depth, previous to 1906, are reported. James Williams drove 70 feet on the outskirts of Chincoteague village some years ago without result, and the United States government attempted to get deep water at the lighthouse on Assateague. This last trial was abandoned when a pipe had been driven to a reported depth of 135 feet.

The quality of the water from the dug and driven wells varies considerably, and is said to be better after a long spell of wet weather than during

a drought. The water level in the interior of the islands fluctuates a couple of feet with the seasonal variations of rainfall, and when the "springs are low" in dry weather many wells yield brackish water.

In the village of Chincoteague driven wells are almost the sole source of supply, not over 25 cisterns being reported in use in 1906. Near the water front many wells have been salted by unusually high tides. Much of the well water is highly colored by iron or organic compounds, but there is great irregularity in this respect—the water from wells less than 20 feet apart differing decidedly in appearance. A sample said to represent a fair average of the wells in town was taken from a tank at the store of D. J. Whealton. This water is drawn by a wind pump from three points driven 14 feet. The results of a field test are given in table 7.

As the demand for domestic purposes is increasing, and present sources of supply at Chincoteague are not altogether satisfactory, the possibility of getting better supplies by wells deeper than any yet sunk calls for investigation. However, it is not likely, in view of what is known regarding the deep flows of the mainland, that good water will be found at great depths, 1,000 feet or more; and the prospects for potable water between 100 and 1,000 feet are not promising.^a

With ordinary precautions against pollution the driven pumps now used will suffice for isolated dwellings. The use of water from surface ponds near dwellings for "drinking" (floating) oysters is decidedly objectionable.

Wells on the bay side at Saxis, Belinda, Marsh Market, and Grotons.—A large number of wells have been driven near Saxis, Belinda, Marsh Market, Grotons, and Justisville and a few of these flow. Details regarding some appear in table 5. The supplies are in some places excellent and in others so hard and iron-bearing as to be unsuited for household use. One well on the steamboat pier at Saxis found water in a bed of coarse gravel under 2 feet of bluish sand indurated enough to be called rock by the driller. The record is as follows:

Well of Baltimore, Chesapeake & Atlantic Steamboat Co., at Saxis.

(Authority, I. B. Clark, driller.)

Material	Thickness (Feet)	Depth (Feet)
Water	6	6
Blue mud	87	93
Bluish rock	2	95
Gravel, with pebbles as large as marbles, water-bearing.....	2	97

^aA deep well is reported to have been drilled in 1910 for a projected fish factory on Assateague Island. The depth of the well and the quality of the water found are not known to the writer.

The water, which is of good quality, rises to tide level.

At a saw mill half a mile east of Belinda belonging to Ross & Hall, two 1½-inch wells were driven, 44 and 46 feet respectively, to the "second spring" to get enough water for a 50-horse power boiler. The water was hard and formed scale. Wells to the "first spring," 8-10 feet, did not get water enough. Half a mile northwest of Belinda a well was driven to the "third spring" finding water in a bluish gray sand containing small bivalve shells. Those washed up by the drill were not identifiable.

A well at the oyster house of M. L. Hall on the outer edge of a wide strip of marsh facing Mesango Creek was driven 64 feet, stopping on "rock." It yields brackish water high in iron that is used for washing oysters and has been tried in a boiler. An 84-foot well at Belinda post-office found water which rose to above tide level, but contained so much iron as to be unfit for domestic use.

At the mill of J. A. Hall at Marsh Market a 2-inch well driven 92 feet struck water which rose to 4 feet above tide or 1 foot below the surface. The yield was insufficient and a 1½-inch well had to be sunk to the sands at 48 feet to get water enough for a 50 horse-power boiler.

Wells on the bay side farther south.—Farther south on the bay side of the county a considerable number of flowing wells, ranging in depth from 36 to 160 feet, have been sunk along Muddy, Hunting, Deep, Chesconnessex, Onancock, Pungoteague, and Nandua creeks, there being probably 30 on Hunting Creek alone. As a rule these wells yield good water which may have (when fresh from the well) a faint odor of sulphur; in places the water is slightly hard and iron-bearing. Details of many wells are given in table 5.

A well on Muddy Creek near Mearsville showed the following succession of materials:

Record of well of W. J. Somers, one mile south of Mearsville.

(Authority, I. B. Clark, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Sand	4	5
Blue mud	75	80
Bluish sand, poor water.....	4	84
Blue mud	33	117
Sand with small shells, good water.....	1	118

This 1½-inch well, according to the driller, flows at an elevation of 61½ feet above tide 1½ gallons per minute.

Between Chesconnessex and Deep creeks, where the ground is so low that shallow wells are liable to be salted by high tides, several deep wells have been driven yielding water of fair quality. The following succession of beds was reported from a well near Deep Creek:

Record of well of Bailey East, one-half mile north of Chesconnessex.

(Authority, Bailey East, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Yellow sand	19	20
Black, bluish, and slate-colored marsh mud.....	19	39
Bluish gray sand; a little water.....	1	40
Loam with smooth pebbles, yellow, gray, black and white; water at base	3	43
Bluish sand, water at base.....	32	75
Coarse gravel, no large stones; water.....	4	79
Bluish sand, with shells at 95-99 feet; water at 37 and 100 feet	58	137

The water from all the four "springs" rose to the level of mean high tide, or within 18 inches of it, and is slightly irony.

Onancock, on Onancock Creek, has a public supply system, but most persons get water from driven wells, many of which go only to the "first spring" at 16 feet. In 1906, seven 2-inch wells at the town waterworks reached various depths—two 16 feet, two 30 feet, and three 50 feet. They were fitted with slotted brass strainers and were, except one, connected to a triplex pump driven by a $\frac{7}{8}$ horse-power gas engine that lifted the water to a 50,000-gallon tank on a steel tower 65 feet high. The wells are driven over a roughly circular area 90 feet in diameter, about 18 feet above mean high tide. The head of the water in the points is said to be about 5 feet above tide. In addition, water is pumped from a dug well 20 feet in diameter and 16 feet deep, in which one of the points to the 50-foot sand is driven. The yield from the driven wells is small and much of the water used comes from the dug well, which serves both as well and reservoir. The total yield is given as 35 gallons per minute.

The following record of one of the pumping-plant wells was given from memory:

Record of well at waterworks, Onancock.

(Authority, F. A. Merrill, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Red clay	3	4
Yellowish sand at base, gravel containing pebbles one-half inch in diameter; water-bearing	12	16
Bluish sand and mud	14	30
Bluish gray sand, water	5	35
Blue mud	15	50
Coarse gray sand with pebbles up to one-half inch; water.....	5	55

A field assay of water drawn directly from the points, and another, by H. N. Parker, of water presumably taken from the dug well are given in table 7.

The water is used in the boiler of vessels belonging to the State oyster navy and in those of steamers running to Baltimore. The bacterial purity of the supplies from the 50-foot bed should be unquestionable but in 1906 contamination of the open well was possible.

In 1906, about one-third of the estimated population, 1,200 people, used this water, the remainder getting supplies from driven wells 16 to 25 feet deep. The yield of the 25-foot wells was said to be small, but the water was pronounced very good.

Several attempts to supply the town from other wells than those now used have been made and two deep wells have been sunk without success. One drilled in 1890 by H. K. Shannahan found water at 90 and 140 feet, and more below to a depth of 486 feet. The casing was broken in an attempt to withdraw it, and the water from the 140-foot sand which rose nearly to surface was used for a few years by means of a wooden pump. The yield was 5 to 10 gallons per minute. The water was not liked because of its "sulphur" odor and the well has been abandoned for years. Another well was sunk in 1895 to about 600 feet without getting a satisfactory supply.

The following incomplete log of the well drilled by Mr. Shannahan is from that published by Darton.^a

^aDarton, N. H.. Artesian well prospects in the Atlantic Coastal Plain, U. S. Geol. Survey, Bull 138, p. 131.

Partial record of well at Onancock.

Material	Thickness (Feet)	Depth (Feet)
No record	150	150
Shells in gravel and sand.....	25	175
No record	5	180
Fine sand; no water.....	25	308
Hard rock 9 inches; clay 2 inches; rock 5 inches; clay 5 inches	2	310
Clay and sand	23	333
Clay and sandy clay	147	480

The 50-foot sand tapped at the waterworks is reported to be water-bearing and to yield no water within short distances. The flowing well of H. L. Hurst, on the edge of the creek, 50 yards from the waterworks, is only 34 feet deep and evidently taps this sand.

At Finney, back of Onancock, are several wells over 50 feet deep. The 83-foot well of W. T. Rogers, according to the owner, went through hard black mud from about 50 to 75 feet, below that dark sand, and below that light sand containing half-inch pebbles. The water does not rise $3\frac{1}{2}$ feet above tide. The head is greatest at high tides or when nearby marshes are flooded after heavy rains. In the springhouse, at the well, are two cement basins from one of which the water is pumped by wind power to a tank. The water fresh from the well, though perfectly clear, has a slight "sulphur" odor; that from the tank is odorless.

At Cashville, south of Onancock, a number of wells from 80 to 100 feet deep have been sunk. The following record is reported.

Record of well of S. Crockett, on Masitank Creek.

(Authority, Bailey East, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil, clay and sand	20	20
Mud	25	45
Blue sand	65	110
Blue sand and clam shells	1	111

This well does not flow, though the water rises to within 1 foot of surface; elevation 6 feet.

The elevation of the higher ground about Cashville is 8 to 10 feet. Dug wells 8 to 15 feet deep yield water of varying quality; those near the creek are sometimes salted by high tides. The water from the deep wells is satisfactory. Most of the drilled wells cost \$35 to \$40, including the $1\frac{1}{2}$ -inch pipe.

At Harborton, which has a population of about 450, are perhaps 20 wells that will flow at an elevation of 8 feet above mean high tide. They all tap a bed of coarse sand and gravel at 140 feet. The water is soft and excellent,

but at some wells it has a slight "sulphur" odor. A well at Allen & Lenner's fish factory, used for boiler supply at the factory and on fishing steamers, may be the oldest flowing well on the Eastern Shore. The water is said to be satisfactory, the boiler being in good condition after 16 years' use. A field analysis of a sample from this well is given in table 8.

The following record is reported by a local driller. Much the same succession was found in other wells in Harborton.

Record of well of J. W. Adams, Harborton.

(Authority, J. W. Adams, owner.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Red clay	4	5
White and yellow sand; water at 12 feet.....	11	16
Blue creek mud	24	40
Gray sand and gravel; water-bearing.....	11	51
Tough blue clay	74	125
Gray sand, fine at top, coarser below, contains hard streaks and shells; water-bearing	15	140

The deeper wells at Harborton have a 4-foot galvanized iron strainer on the 1½-inch pipe. The casing is usually just long enough, 50 to 55 feet, to cut off the water in the second sand. In a few wells casing is carried to the bottom because of running sand. At a number of the wells are wood or cement tanks into which the water rises and from which pitcher pumps lift it to sinks, etc.

One driller, who furnishes all labor and necessary tools and works on a "water or no pay" basis, charges 45 cents per foot for the first 100 feet and 35 cents for each additional foot. Another driller charges \$50 for sinking 140 feet.

A well at Boggs Wharf about one-half mile above Harborton passed through beds of the same general character as those at Harborton, as indicated by the record below.

Record of well of H. Battail, near Boggs.

(Authority, I. B. Clark, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Red clay	3	4
White sand; poor water	6	10
Blue mud	34	44
Blue sand; very little water.....	1	45
Blue mud	59	104
Shells in bluish sand rock	8	112
Blue mud, shells and sand rock, four layers of rock in all.....	38	150

In a moderately coarse greenish-gray sand, not glauconitic, at 150 feet were small bivalve shells. Specimens of these examined by Dr. W. H. Dall were pronounced probably Miocene. The water rises about 4 feet above surface or about 9 feet above mean tide. The quality is good.

Another well a few hundred yards distant showed much the same succession of material.

Record of well of Richard Taylor, at Boggs.

(Authority, I. B. Clark, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Red clay	4	5
Yellow sand	5	10
Blue mud	94	104
Bluish gray sand with small shells.....	1	105

At the mouth of this well is a cement tank. The head is about 8 feet above mean tide.

At Pungoteague village, population about 350, several dug and driven wells sunk to the "first spring," 10 to 18 feet, came under suspicion during an outbreak of typhoid fever, and a number of deeper wells have been put down since. One of these, 210 feet deep, or 190 feet below tide level, is the deepest in use in Accomac County. It cost \$120. The driller reported the following succession of beds:

Record of well of S. W. Ames, Pungoteague.

(Authority, I. B. Clark, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Yellow sand	15	16
Blue mud, at 40 feet, and 60 feet, slightly sandy, with a little water, at latter point; bluish sand with shells.....	94	110
Blue mud	3	113
Bluish sand with shells and wood.....	95	208
Sand; good water	2	210

The well throws considerable sand when pumped hard. The sand is fine, white, well rounded and contains bits of lignitic material. A complete analysis of a sample of water from this well is given in table 8.

There are known to be five water-bearing horizons of varying extent at Pungoteague; the first, at 15 to 25 feet, gives plenty of "medium soft"

water containing little iron; the second, at 30 to 40 feet, gives hard, iron-bearing water; the third, at 62 feet, yields water containing little iron; the fourth is at 110 feet; and the fifth at 208 feet gives good water.

Near Craddockville are several flowing wells. The following is a log of one of them.

Record of well of L. J. Nielson, Allen Farm, 2 miles northwest of Craddockville.

(Authority, I. B. Clark, driller.)

Material	Thickness (Feet)	Depth (Feet)
Blue mud	140	140
Blue sand and shells	33	173

This well was dry when completed, and the water at 170 feet broke in some 48 hours after the driller had stopped work.

Wells along the line of the New York, Philadelphia & Norfolk Railroad.—At the villages south of New Church driven wells reach the “first spring” at 10 to 15 feet; most of them find soft water, but some find decidedly iron-bearing water. The deeper sands frequently yield better supplies.

At Hallwood are two wells over 100 feet deep. The log of one is given below.

Record of well of Jas. A. Hall, at Hallwood.

(Authority, I. B. Clark, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Pipe clay, sand and gravel, with water below 10 feet.....	29	30
Blue mud	80	110
Bluish sand with shells; small yield of good water.....	40	150
Blue mud	36	186

The yield by a pump was so small that though the water was of good quality, the well was abandoned.

A tank of the New York, Philadelphia & Norfolk Railroad is supplied from a dug well 12 feet deep and from sixteen 2-inch points driven to varying depths. An analysis of the water from the dug well is given in table 7. A partial analysis made by C. B. Dudley for the Pennsylvania System showed 4.91 grains per gallon of total solid residue consisting chiefly of sulphate of lime and magnesia with no carbonates; a slightly corrosive water.

Parksley, one of the largest villages along the railroad, population 500, has no public supply system; nor were drilled wells over 40 to 50 feet deep reported from the village.

At Accomac, the county seat, water is obtained from three sandy beds lying 12, 30, and 50 feet respectively below surface. The water from the first is soft, but that from the second is iron-bearing, and that from the third is soft. The following generalized section is given by a driller who has sunk many wells in the county.

General section at Accomac.

(Authority, I. B. Clark, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Red clay	3	4
Yellow and white sand; surface water at 12 feet, better water at 32 feet.....	28	32
Sticky blue mud	18	50
Coarse bluish sand, gravel, and small shells; good water.....	1	51

Field assays of samples from three wells are given in table 7.

Near Tasley dug and driven wells average 10 to 15 feet deep and many get water that contains a little iron. Water of better quality is said to be found at 20 feet. The railroad tank is supplied from eighteen 2-inch points driven to varying depths, said to be 22, 35, and 50 feet.

A partial analysis by C. B. Dudley, of water from a well 12 feet deep, showed 4.21 grains of total solid residue per gallon, consisting chiefly of sulphates of lime and magnesia with some chlorides and no carbonates; a slightly corrosive water.

No wells over 55 feet deep had been driven at Onley, 3 miles south of Tasley, and there were only two over 50 feet; most were 10 to 20 feet deep. The following record shows the character of the materials overlying the "second spring."

Record of well of I. W. Rogers at Onley.

(Authority, I. B. Clark, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Light gray clay	9	10
Yellow sand, full of water	8	13
Blue mud	35	53
Coarse gravel and pebbles; water-bearing	2	55

About Keller dug wells get water at 8 to 10 feet and are nearly full in wet weather. Driven wells tap sandy beds at 8 to 20 feet. One taps a sand at 60 feet.

Wells on the ocean side south of Chincoteague Bay.—On the ocean side of the county, south of Chincoteague Bay, flowing wells have been drilled along the inlets, the best flows, as on the bay side, being at the base of steep slopes facing open water or marshes. The first attempt it is said, was at the residence of B. T. Gunter, 4 miles southeast of Accomac, in 1899. This well gets water, which rises about 3 feet above the level of mean high tide, from a sand bed at 122 feet below surface. A windmill elevates the water to a tank whence it is piped to the house.

Another flowing well on Custis Neck, $\frac{3}{4}$ -mile southeast of the well just mentioned, is 104 feet deep and flows 100 gallons an hour at an elevation of 1 foot above the surface or about 4 feet above mean high tide; the following record was given by the driller.

Record of well of G. L. Dougherty, one and one-half miles north of Locustville.

(Authority, I. B. Clark, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil, sand, clay; surface water.....	20	20
Blue mud	35	55
Sand; flow of salt water	5	60
Blue mud	40	100
Sand; flow of good water	4	104

At Wachapreague, on the head of Wachapreague inlet, east of Keller, practically all the driven wells get water from the "first spring" at about 10 feet. Along the edge of the marsh at the head of the inlet this water is brackish. A large hotel supplies cistern water for drinking.

Wells on islands in Chesapeake Bay.—The Chesapeake Bay islands included in Accomac County are low, like those on the ocean side; and some are mere patches of salt marsh. The largest of the islands, Tangier, has a population of over 1,200 persons. Most of the dug wells on this island are less than 9 feet deep. The water at some wells is soft and at others, particularly near the shoreline, hard or irony. These shore wells frequently get brackish in droughts or after unusually high tides. Shallow driven wells which yield water of much the same quality as the dug wells are preferred for sanitary reasons.

The only attempt at deep drilling reported is a well driven to 250 feet for J. J. Daly near the center of the island in 1906. A bed of very fine sand 65 feet thick containing salty water which rose to within a few inches of the surface was struck at 141 feet; "rock" at 165 feet, and black mud, "rotten sea-grass and clam shells" at 200 feet and below. No large supply of water was found below 141 feet, and the sand at that depth clogged the pipe.

On Watts Island the deepest well in 1906 was about 70 feet and on Fox Island the deepest was 76 feet. On the latter island a number of wells have been driven by William Ellinger for use at oyster houses. The following carefully kept record shows the character of the beds penetrated:

Record of well on Fox Island.
(Authority, William Ellinger, owner.)

Material	Thickness (Feet)	Depth (Feet)
Marsh sod	1	1
Marsh mud	6½	7½
Stiff, yellowish-red clay	4½	12
Blue mud	15	27
Conglomerated shells, pebbles and gray limy clay.....	7	34
Stiff, gray clay	15	49
Hard substance called "coral rock" by driller.....	1	50
Tough gray clay	13	63
Sand and clay	5	68
Sharp gray or white, fine to coarse quartz sand.....	6	74
Coarse gravel; water	2	76

The water which rises to within 2 feet of the surface of the marsh, the level fluctuating with the tide, is hard and slightly iron-bearing. The yield with a No. 3 pitcher pump is 10 to 15 gallons per minute. The quality of the water is shown by the field assay in table 7.

The chances of getting plenty of deep water on these bay islands, particularly on Tangier, is so promising that a test by deep drilling should be made. The fine wells on the Great Wicomico River, Virginia, and at Crisfield, Maryland, indicate that abundant flows may be had at about 1,000 feet below sea level in the Upper Cretaceous beds. The water will probably be fully as mineralized as that at Crisfield and may be salty.

Some shallow-well details reported by postmasters are summarized below:

Details of shallow wells in Accomac County.

Post-office	Depth of wells (Feet)	Material of water bed	Quality of water
Assawoman	10-25	 sand	soft
Atlantic	10-25	 clay and sand	hard
Bullbegger	8-25	 sand	bad, irony
Fairoaks	8-16	 sand	
Graysville	8-12	 sand	soft, bad, salty
Horsley	10-40	.....	{ shallow, irony; deep, good
Leemont	10-18	.....	ditto
Onley	10-28	 sand and gravel	soft
Parksley	8-16	.....	hard, irony
Poulson	5-20	 sand	
Sinnickson	6-40	 clay and sand	poor
Temperanceville	10-25	 sand	fair, irony

Conclusions.—By sinking to one or another of the sandy beds above 300 feet it is possible at most places to get supplies of water of satisfactory quality. Owing to their easy pollution dug wells are objectionable. Driven wells can be sunk cheaply and water from those 30 feet or more deep should be free from disease germs.

The outlook for satisfactory water from beds in the Chesapeake deposits 300 feet or more below surface is not especially good. On the mainland in the northern part of the county there is a chance of getting potable water at greater depth, 1,000 to 1,500 feet in the Raritan, but drilling in the hope of reaching better supplies in the Potomac beds, 2,000 feet more below surface, is not advisable. In the southern part of the county deep well prospects are less promising than in the northern.

ALEXANDRIA COUNTY.

General description.—This county, once part of the District of Columbia, is the smallest and most densely populated county in Virginia. The area is 32 square miles. The topography is varied, elevations ranging from sea level to over 400 feet. In places on the heights above 300 feet are remnants of the Lafayette terrace, and several of the Columbia terraces are plainly traceable, particularly the Sunderland at 260 feet near Ballston and Glen Carlyn. The city of Alexandria stands on a somewhat eroded terrace 40 to 50 feet high.

The crystalline rocks, mostly granite and gneiss, outcrop and are quarried along the river above Rosslyn and are exposed in ravines in the western part of the county.

The cobbles, sands, and clays, of the Patuxent formation (Potomac group) outcrop here and there. Northwest of Alexandria the higher (Patapsco) beds rest on gneiss and granite at elevations up to 250 feet above tide, whereas the base of the Patuxent is over 450 feet below tide at the river front in Alexandria.

The Columbia formations contain characteristic cobble beds, sands, and loams. The more highly colored loams of the Lafayette formation are found on the remnants of the high plain between Cherrydale and Falls Church, at Upton Hill, and elsewhere.

UNDERGROUND WATERS

Occurrence and quality.—In Alexandria County water is obtained from the crystalline rocks, from their decayed upper surface, and from Potomac, Lafayette and Columbia sands. Because of this difference of origin the quality varies. Generally the waters are soft; in places they are hard and some deep wells and occasional shallow wells have found water containing considerable iron. In general the water of the deep drilled wells, particularly those at Alexandria, is beyond suspicion, but into many open shallow wells, in places where there is lack of proper curbing, surface impurities are washed at every rain.

Springs.—As a result of an abundant rainfall, and a deeply scored topography, Alexandria County has many springs. They issue from hollows, from hillsides, in ravines, or at the base of terrace scarps. Most of them flow from sandy beds in the Columbia, but a few flow from hard rock. Many of the springs are utilized for household supply or for watering stock, while three are, or have been, of commercial importance. These are the Hume, near St. Asaph, the Erup near Glencarlyn, and the Powhatan south of Upton.

Hume.—This spring or springs, for there are two distinct sources, in the valley of Four Mile Run, is said to have been discovered by troops during the Civil War. It has been improved by a concrete basin, piping, etc. The flows issue from Columbia sands on a terrace. The principal flow, about 10 gallons per minute, is said not to vary with the seasons. The water contains iron and according to some persons, has a slight sulphur odor. It is not sold by the owner, but has been collected and sold by others.

Erup mineral spring.—This spring, about half a mile south of Glencarlyn Station, issues from a high-lying sand and cobble bed. The flow is about 1 gallon per minute. Over the spring is a frame spring house, adjoining this is a frame bottling house with cement-lined iron tanks. The water, which is clear, colorless and odorless, is said to carbonate well. It has been shipped to Washington and sold there, plain or carbonated, for table or medicinal use.

The water has been analyzed several times; the following analysis shows its low mineral content.

Analysis of Erup mineral spring water.

(J. K. Haywood, analyst.)

	Parts per 1,000,000
Silica (SiO_2)	7.9
Sulphuric acid radicle (SO_4)	3.3
Bicarbonate acid radicle (HCO_3)	9.1
Chlorine (Cl)	6.3
Bromine (Br)	none
Iodine (I)	small amount
Iron (Fe)	.1
Manganese (Mn)	none
Calcium (Ca)	2.9
Magnesium (Mg)	1.8
Potassium (K)	1.5
Sodium (Na)	5.7
Lithium (Li)	trace
Oxygen to form oxide of iron (Fe_2O_3) and silicic acid radicle (SiO_2)	1.2
Total	38.8
Total solids	47.8

HYPOTHETICAL COMBINATION

Lithium chloride (LiCl)	trace
Potassium chloride (KCl)	2.9
Sodium chloride (NaCl)	8.1
Potassium iodide (KI)	small amount
Sodium sulphate (Na_2SO_4)	4.6
Magnesium sulphate (MgSO_4)	.3
Magnesium bicarbonate ($\text{Mg}(\text{HCO}_3)_2$)	10.2
Calcium bicarbonate ($\text{Ca}(\text{HCO}_3)_2$)	.8
Calcium silicate	7.9
Silica (SiO_2)	3.8
Ferrie oxide (Fe_2O_3)	.2
	38.8

Powhatan.—This spring is situated about three-eighths of a mile south of Kearney station on the Washington, Alexandria & Great Falls electric

railway. It issues from the south side of a ravine, the valley of a small rill that empties into Four Mile Run less than half a mile east of the spring. A dark granite outcrops in the ravine, and the spring is probably of the crevice type, though the point of emergence from the rock is not visible. The coolness of the water indicates a source deeper than that of many hillside springs. The flow is about 10 gallons per minute; the quality clear, tasteless, and odorless. The spring basin is protected by a masonry chamber; there are no possible sources of pollution near, and the sanitary conditions are good.

There is a masonry bottling house at the spring from which water has been shipped to Washington. The following analysis was made by the Bureau of Chemistry.^a

Analysis of Powhatan spring water.
(J. K. Haywood and B. H. Smith, analysts.)

	Parts per 1,000,000
Silica (SiO ₂)	12.0
Sulphuric acid radicle (SO ₄)	1.2
Bicarbonate acid radicle (HCO ₃)	12.0
Nitric acid radicle (NO ₃)	1.55
Nitrous acid radicle (NO ₂)	.016
Phosphoric acid radicle (PO ₄)	none
Metaboric acid radicle (BO ₂)	none
Arsenic acid radicle (AsO ₄)	none
Chlorine (Cl)	3.8
Bromine (Br)	none
Iodine (I)	trace
Iron and aluminum (Fe + Al)	.2
Manganese (Mn)	none
Calcium (Ca)	1.6
Magnesium (Mg)	1.2
Potassium (K)	1.2
Sodium (Na)	3.7
Lithium (Li)	none
Ammonia (NH ₄)	.069
Oxygen to form Fe ₂ O ₃	.10
Total	38.435
Free ammonia	.065
Albuminoid ammonia	none
Nitrogen as nitrates	.350
Nitrogen as nitrites	.005
Oxygen required	.45

^aHaywood, J. K., and Smith, B. H., Mineral Waters of United States, Bull. 91, Bureau of Chemistry, 1905, p. 43.

Analysis of Powhatan spring water—(Continued).

HYPOTHETICAL COMBINATION		Parts per 1,000,000
Ammonium chloride (NH_4Cl})	.....	0.207
Potassium chloride (KCl})	.....	2.3
Sodium chloride (NaCl})	.....	4.3
Potassium iodide (KI})	.....	faint trace
Sodium sulphate (Na_2SO_4)	.....	1.8
Sodium nitrate (NaNO_3)	.....	2.12
Sodium nitrite (NaNO_2)	.....	.024
Sodium bicarbonate (NaHCO_3)	.....	2.9
Magnesium bicarbonate ($\text{Mg}(\text{HCO}_3)_2$)	.....	6.0
Calcium bicarbonate (CaCO_3)	.....	6.5
Ferric oxide and alumina ($\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$)	.....	.3
Silica (SiO_2)	.....	12.0
Total	.....	38.451

Public supplies.—The city of Alexandria, population about 17,000, is supplied with water taken from a creek, Cameron Run, about 3 miles above the city. The military post of Fort Myer is supplied with water from Potomac River.

LOCAL SUPPLIES

Alexandria.—There are a number of dug wells owned by the city and many privately owned ones. These wells 20 to 40 feet deep get water from sandy and gravelly Columbia beds. In 1906 some were liable to pollution from leaky sewers or cesspools.

Deep wells have been drilled for the Robert Portner Brewing Co., the Mutual Ice Co., the Alexandria Fertilizer and Chemical Co., and the Belle Pré Bottle Co. At the Portner brewery, on a slope 40 feet above tide, are four 8-inch wells down about 400 feet and one 6-inch well down 61 feet, the greatest depth of well reported being 430 feet. The wells are pumped by air lift. The water is low in lime but alkaline enough to make an admirable boiler water. It is used for brewing, for ice-making, and for washing as well as for steam production. A number of families in the vicinity of the brewery get the water for drinking. The water from the 61-foot well contains considerable iron and is used only for cooling condenser coils and washing the outside of kegs and barrels. Analyses of water from two of the deep wells, made in 1903, are given below. Well No. 1 had been in use 20 years; well No. 2 had just been completed.

Analyses of water from wells of Robert Portner Brewing Co., Alexandria.
(First Scientific Station for the Art of Brewing, analyst.)

	Parts per 1,000,000	
	No. 1	No. 2
Total solids	118.0	170.0
Organic and volatile matter	12.0	14.0
Iron and aluminum oxides ($\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$)	trace	4.0
Calcium (Ca) .....	.....	.....
Magnesium (Mg) .....	.....	.....
Chlorine (Cl)	24.8	19.5
Alkaline carbonates	114.4	109.0
Sulphuric acid (SO_3)	11.6	12.0
Nitric acid	0.0	0.0
Nitrous acid	0.0	0.0
Free ammonia	trace	trace
Albumenoid ammonia	small trace	small trace
Total hardness	15.6	20.0

A later analysis made by the United States Geological Survey is given in table 11.

The 8-inch well of the Peoples Ice Company is on the river front. It is 401 feet deep and cased to the bottom. The water rises about to tide level, 12 feet below the top of the well. Pumping 90 gallons a minute lowers the water to 60 feet from the top. The water, like that from the Portner wells, is colorless, odorless, and tasteless. It is used for making ice and has been bottled and sold for table use under the name of Mico water. An analysis furnished by the company but recalculated to express results in the form adopted by the U. S. Geological Survey shows the following mineral content:

Analysis of Mico Water.

(J. D. Hird, analyst.)

	Parts per 1,000,000
Total solids	176.
Organic matter	0.
Silicia (SiO_2)	21.
Calcium (Ca)	trace
Magnesium (Mg)	1.4
Sodium (Na)	49.
Bicarbonate radicle (HCO_3)	39.
Sulphate radicle (SO_4)	36.
Chlorine (Cl)	32.

A well sunk in 1906 at the plant of the Alexandria Fertilizer and Chemical Co., on the water front a quarter of a mile north of the well of the Peoples Ice Co., illustrates the variability of the Patuxent sands as

water bearers, the poor quality of the water in some of the sands and the difficulties that beset a driller unaccustomed to working in the Potomac sands and sandy clays.

A standard cable rig was used and rapid progress made for the first 250 feet. Below 300 feet progress was slower and the 8-inch casing after a series of accidents finally collapsed at 397 feet. An attempt to go deeper with 6-inch casing resulted in reaching a total depth of 445 feet, beyond which it was impossible to drive the casing, though this was heavy pipe, without its collapsing. Little water was found and none that would flow at surface, 10 feet above tide. Dynamiting at 350 feet gave a small yield which rose to 80 feet of surface. Dynamiting at 225 feet gave water which rose nearly to tide level. The yield is 60 gallons per minute, by air lift, the end of the air pipe being 215 feet down the well.

The water from the sand and gravel at 225 feet has not improved in quality under heavy pumping. It is clear and colorless when fresh from the well but becomes turbid and deposits iron on standing. It has an acid reaction and is not suitable for boiler use. A partial analysis showed solids amounting to 1,265 parts per million, chiefly sulphates.

A 6-inch well drilled for the Belle Pré Bottle Co., half a mile northwest of the brewery, is 185 feet deep; the water, from a sand bed in the Patuxent formation, rises to 25 feet of surface, elevation 40 feet; pumping 65 gallons lowers it 10 feet. It is used for boiler supply, though it forms a tough hard scale, and for other purposes at the company's glass works. The analysis in table 11 was made by the U. S. Geological Survey in 1910. The difference between this water and that from the deeper wells is marked.

Other localities.—On the heights west of Alexandria most residences get water from dug wells; a few have drilled wells. The supplies come from Columbia or Potomac sands and cobble beds. Depths to water and quality of supplies vary. Thus a drilled well about 125 feet deep on the southeast slope of Shooter Hill obtains iron-bearing water that rises to 60 feet of surface from a Patuxent sand bed; whereas about 100 yards east, and a little higher up the hill, a well only 20 feet deep yields an abundant supply of soft clear water. At most wells the water is soft.

The irregular occurrence of water in crystalline rocks in the western part of the county is shown by the following records furnished by N. H. Darton. The second well is 150 feet east of the first.

Record of well of G. N. Saegmuller, Chain Bridge.

(Authority, W. C. Miller, driller.)

Material	Thickness (Feet)	Depth (Feet)
Micaceous red clay	60	60
Soft micaceous rock	10	70
Gneiss	485	555

A little water, about 2 gallons per minute, was found at 80 feet and no water below.

Record of well of G. N. Saegmuller, Chain Bridge road.

(Authority, W. C. Miller, driller.)

Material	Thickness (Feet)	Depth (Feet)
Micaceous red clay	60	60
Soft micaceous rock	11	71
Gneiss	10	81

The yield of this well was 8 gallons per minute.

The record of another well that obtained water from granite is given below.

Record of well of A. M. Lathrop, Upton Hill, near Fostoria.

(Authority, W. C. Miller, driller.)

Material	Thickness (Feet)	Depth (Feet)
Micaceous red clay	60	60
Soft micaceous rock; small supply of water at 60 feet.....	34	94
Soft gneiss	80	172

According to the driller, this well, when completed, yielded 15 gallons per minute of excellent water.

About Addison and Arlington Junction are many dug wells and a few drilled wells. The dug wells are 15 to 25 feet deep. The drilled wells vary greatly in depth. One at the power house of the Washington, Alexandria & Mt. Vernon railway, near Luna Park, yields a small flow of good water from a sand bed reported to be but 36 feet below surface. The comparatively high head of the flow, about 20 feet, is explainable by the water bed receiving supplies from the hill on the Luna Park grounds, and thus having an initial head of possibly 100 feet. At the plants of the Standard Brick Co., and of the New Washington Brick Co.

near Addison are wells 140 feet and 131 feet deep respectively, tapping Patuxent beds. The water is used for boiler supply and for drinking. An analysis of the water from one of the wells appears in table 11.

There are no deep drilled wells at Rosslyn. Most dug wells obtain soft water from Columbia or Potomac sands and cobble beds. Depths range from 15 to 40 feet.

On the terrace near Ballston, Clarendon, Veitch and Kearney, dug wells about 20 feet deep are practically the sole source of supply. The water lies chiefly in Columbia sands or cobble beds and is soft at most wells; a few wells yield hard water and a few water that is irony.

About Glen Carlyn dug wells are 20 to 35 feet deep. The water, in Columbia cobble beds, is soft as a rule.

Falls Church lies chiefly in Fairfax County and its water supply is described under that county.

Conclusions.—The underground water resources of Alexandria County are considerable and can meet far greater demands than those at present made. At Alexandria and along the river front northward, it will probably pay any concern using large amounts of water to have a competent driller make a test to bed rock. Exact prediction of depth to good boiler water at a particular point is impossible. It is probable that such water will be found within 100 feet of bed rock, that a deep well will penetrate a number of water-bearing sands, and that wells a short distance apart will get water of different quality from about the same depth.

Deep drilling on the higher terraces to develop water in the crystalline rocks is a more uncertain venture. It will often be justified by sanitary considerations.

CAROLINE COUNTY.

General description.—Caroline County, formed in 1727 from portions of Essex, King and Queen, and King William counties, lies in the western part of the Coastal Plain between Rappahannock and Mattaponi rivers and extends into the Piedmont region.

The topography is of the western shore type. On the highest terraces are patches of swamp in which head sluggish brooks that meander to the edge of the terrace, then descend rapidly through sharply cut valleys to the lowest terrace. Elevations range up to 250 feet. The Lafayette terrace caps divides in the western end and the Sunderland terrace occurs on the divides in the eastern end of the county. Lower terraces make the second and first bottoms of Rappahannock and Mattaponi rivers.

The oldest rocks exposed at the surface within the Coastal Plain part of the county are the Triassic sandstones and shales in the valley of the South Anna River. The sands, gravels, sandstones, and clays of the Potomac, the greensands of the Pamunkey, and the clays and sands of the Chesapeake all outcrop.

UNDERGROUND WATERS

Because of the topography and because of the variability in composition of the surficial deposits, the depth to the water table and the character of the ground water vary greatly. On projecting headlands of the Lafayette or Sunderland terraces dug wells may have to go 60 feet to get water, while on level interstream areas of the same formation wells may find sufficient supplies within 12 feet of surface and be full to the top after prolonged rains. On the lower terraces the differences in depth to water are less but the wells are more apt to go dry in drought. The sands of the high terraces yield water that is mostly soft but in places it is hard. Waters in the lower terraces are more apt to be hard or iron-bearing. Wells sunk through the terrace formations or through valley wash into the Chesapeake deposits obtain water that may be soft; if the water comes from a bed of shell marl it may be decidedly hard. Supplies may be scanty, though the wells penetrate the clayey sands for 50 feet. The Potomac and Pamunkey sands, tapped by drilled wells along Rappahannock River, yield flows of soft water of good quality that has a faint "sulphur" odor.

Springs.—Because of the topography Caroline County contains many springs of the Coastal Plain type. They are comparatively little used for household supply and none is of commercial importance. One near Guineys has a local reputation for yielding water of therapeutic value.

Wells.—Dug wells, most of them having a wood curbing at the bottom, are the chief source of supply. There are comparatively few driven wells in the county and perhaps 10 drilled wells along Rappahannock River.

The usual price for digging a well is \$5. This does not include extra labor needed and lumber used for curbing.

LOCAL SUPPLIES

Bowling Green.—Practically all the water used in this village, the county seat, is obtained from dug wells 25 to 35 feet deep which give enough water for household use, but few withstand continued heavy pumping after prolonged dry weather. Some of the wells are poorly located.

According to R. P. Vincent, there are about 60 dug wells in the village. He gives the following as an average section of the materials penetrated.

Generalized section at Bowling Green.

(Authority, R. P. Vincent.)

Material	Thickness (Feet)	Depth (Feet)
Red loam	7	7
Red loam and pebbles	7	14
Yellow sandy clay, with seeps of water.....	12	26
Gray sand, main supply of water.....	6	31

The supplies show unexpected variations in quality, due either to the chaotic assortment of materials in the basal beds of the Sunderland formation or to some wells striking shell beds in the Chesapeake. The water from the public well in front of the old courthouse is soft and contains little iron, while almost directly across the street, the well of R. P. Vincent gives water that is hard and contains iron. The village has a reputation for healthfulness, so the supplies obtained from the dug wells are presumably satisfactory from a sanitary standpoint.

Results of field assays of the water from neighboring wells appear in table 7.

Other localities.—At Milford on Mattaponi River the dug wells average 20 feet deep, and get water from sandy and gravelly Columbia beds. The water in a number of the wells is decidedly irony.

The dug wells at Port Royal go deeper than at Milford; some pass through the Columbia sands and get hard water in the Pamunkey greensands at 20 to 25 feet. The artesian wells at or near Port Royal tap coarse greensands and gravels at the bottom of the Aquia formation. The water is beautifully limpid, has a faint "sulphur" odor and is distinctly alkaline.^a One of these wells, owned by the corporation of Port Royal, is on the river edge just below the steamboat landing. It is 272 feet deep, 1½ inches in diameter, and flows 2 gallons per minute, the flow varying slightly according to the stage of the tide. An attempt to get a supply on the terrace, elevation 20 feet, by a ram, proved disappointing and was abandoned. The other wells at and below Port Royal get water from the Aquia. A few wells farther up stream get water from "quicksand" in the Potomac. One of these wells at Hayfield farm near Horseneck is 169 feet deep and just flows at an elevation of 25 feet above tide. The driller reported the following log:

^aFor field assay of water, see table 9.

Record of well of A. B. Lewis, 9 miles southeast of Fredericksburg.

(Authority, Geo. Heflin, driller.)

Material	Thickness (Feet)	Depth (Feet)
Red clay and gravel	20	20
Blue marl; water at bottom; this water cased off.....	80	100
Quicksand, "green with white spots"; main flow at 167 feet...	67	167

The following summarized statement shows the variations in depth to water and quality of supplies at several localities dependent on dug wells. The data are from reports by postmasters and others.

Details of dug wells in Caroline County.

Post-office	Depth of wells (Feet)	Water bed	Quality of principal supply
Brandywine	25 to 45	.....	Hard, soft
Central point	40	.....	.....
Chilesburg	16 to 24	Clay and gravel	Soft
Delos	10 to 20	Sand	Soft
Edgar	25 to 40	Iron crusts	Shallow, soft; deep, hard
Ezra	30 to 50	Gravel	Soft
Golansville	16 to 50	Gravel	Soft
Guineys	15 to 25	Sand, blue clay	Fair, irony
Milford	10 to 60	Sand, gravel	Soft, irony
New London	30 to 35	.....	.....
Penola	10 to 75	.....	.....
Return	40	.....	.....
Rappahannock Academy.	20 to 45	.....	.....
Woodford	12 to 30	Gravel	Soft

Conclusions.—Except at a few villages present supplies of water are equal to local demands. Water that is above suspicion of pollution can be had from the Pamunkey and the Potomac sands by properly drilled wells, but flows are not to be expected at over 25 feet above sea level.

At Bowling Green excellent water for domestic use can be had from the Pamunkey at a probable depth of 400 feet. As this water will not rise within 100 feet of surface, the well would have to be pumped, hence should be of sufficient diameter. At Milford a flow at the surface from either Pamunkey or Potomac sands is doubtful. Enough water to keep fire tanks full and supply several buildings can be had on the terrace at Port Royal by attaching a hydraulic ram to a carefully drilled and cased well of larger diameter than those now in use. On the Mattaponi no artesian wells have been sunk, but flows may be struck at 300 feet below

tide level at the east line of the county. In general flows are not to be expected and supplies that will rise 20 feet above river level are unlikely. There is a good prospect for flows at less elevation east of Penola. The Newark rocks on the North Anna River are uncertain water-bearers, as shown by the deep well at Doswell.

CHARLES CITY COUNTY.

General description.—Charles City County, one of the original shires of the colony of Virginia, was formed in 1634. It extends along the north side of James River to the eastern end of the peninsula between James and Chickahominy rivers.

Away from the rivers the western end of the county has a gently rolling surface, cut here and there by some tributary of the James or the Chickahominy. An altitude of 200 feet is reported just south of Roxbury. This high point is a remnant of the Lafayette terrace, and other remnants of the Lafayette terrace may be seen northeast of Malvern Hill. The lower terraces are plainly evident in the east end of the county. On the James the development of the Wicomico terrace gives the topography a peculiar, drowned look; red hills, remnants of the Sunderland terrace, project above the buff loams and clays of the Wicomico plain. This is particularly noticeable on the road from Charles City to Richmond, between the Willcox Wharf road and Herring Creek. Along the Chickahominy which, above Providence Forge, flows for 40 miles through a narrow swamp, a low terrace is well developed.

The Columbia or the Lafayette overlies the clays, sands, and marls of the Chesapeake, on the higher land in the eastern part of the county. The Chesapeake is probably not more than 120 feet thick, thinning toward the west. Along James River, from the west line of the county to Herring Creek, the greensands of the Pamunkey lie just below the Columbia and are exposed in bluffs. The Chickahominy has not cut its way down to the Pamunkey, though at Roxbury the cover of Chesapeake is less than 50 feet thick.

UNDERGROUND WATERS

Occurrence and character.—Supplies of underground water sufficient for the needs of farm houses can be obtained on the terraces from wells sunk in the Lafayette or the several Columbia formations. The depth to the water table varies according to topography, depth of the surficial deposits, freedom of ground water movement, etc. Some anomalous conditions

result. For instance, near Shirley some wells on projecting headlands of a Sunderland plain get water at 15 feet in loam, while on the Wicomico terrace 50 feet below and not over 300 yards distant, wells go 30 feet to water. The quality of the supplies from the Sunderland and Wicomico formations varies, but is generally soft. On the stretches of a low-lying terrace near James River, excellent water can be had by driven points 20 to 30 feet deep. Water from shallow wells in the Chickahominy valley has a bad reputation, being thought to cause malaria, and intestinal diseases. Part of this ill-repute is no doubt due to the use of dug wells.

Springs.—Charles City County has its share of springs, most of which are of the ordinary Coastal Plain type, flowing from terrace gravels above Chesapeake or Pamunkey beds of sandy clay. The flows are small, probably averaging less than 5 gallons per minute, but the waters are soft. No spring is the site of a health or pleasure resort, and from none is water shipped in commercial quantities. A few that are noticeable for one reason or another are those of John Ruffin, 6 miles west of Charles City; E. A. Saunders at Buckland Farm in the same section; and R. W. Swift 2 miles southeast of Elko. The last, situated in a hollow by a run that empties into Chickahominy River, has a fine flow of 20 to 25 gallons per minute from clayey and sandy beds near the bottom of the Wicomico formation. Other good springs are found along the same run. The water from Mr. Swift's spring is clear and sparkling, and is used for all domestic purposes. A field assay is given in table 6.

Wells.—The dug well, cased with wood, is the chief source of underground water supply. In places on the lower terraces along James River driven wells are used. There are few deep drilled wells, though water-bearing beds in the Pamunkey or Potomac underlie the entire county.

LOCAL SUPPLIES

Of the deep wells reported, one 280 feet deep, near the Chesapeake & Ohio railroad station at Roxbury, on the edge of the cypress swamp along Chickahominy River, was drilled for T. L. Watson to furnish drinking water of better quality than could be procured by dug wells, and to supply a mill boiler. The water rises to within 2 feet of surface, or about 40 feet above mean high tide in James River. According to unverified reports a small flow was struck at 70 feet, but was cased off. The main flow is from a Potomac gravel bed. The water, pumped by a windmill, is clear and soft with a very slight sulphur taste. It works nicely in a boiler, and is called an excellent table water.

One of the finest wells in the section along James River was sunk for W. M. Ramsey, on the famous estate known as Westover. The well, which is 10 inches in diameter and 139 feet deep, found water in a bed of gravel and black sand (basal Pamunkey) at 132 feet; this water rises to 10 feet of surface, or 10 feet above mean high tide. Pumping 70 gallons per minute lowers the water 8 feet. A 4 horse-power gas engine belted to a horizontal pump, forces the water to a tank whence it is piped to the house, stables, and other buildings. The water is clear, tasteless, and odorless.

At Bucklands stock farm, near Bucklands Landing on James River, are 6 flowing wells ranging in depth from 168 to 184 feet that reach Pamunkey sands. The flows are free, ranging from 6 gallons through a 2-inch pipe, at the well on the highest ground, elevation 24 feet, to 80 gallons per minute at a well by the river. The reported head of the flows is about 32 feet above river level. (See table 5.)

Near Charles City dug wells are found 25 to 40 feet deep, averaging 30 feet, and ordinarily contain 4 or 5 feet of water. In most wells the water is called hard.

The following section in a road cut at Courthouse Creek shows the general character of the Columbia and Chesapeake beds reached by dug wells.

Section at Courthouse Creek, Charles City.

Material	Thickness (Feet)	Depth (Feet)
Gray, buff, and red loam and clay.....	10	10
Discontinuous band of cobbles	1	10
Gray sand	3	14
Iron crusts and sand	2	16
Coarse yellow and orange sand	10	26

Near Binn's Hall dug wells are 12 to 60 feet deep, most being from 12 to 25 feet; the water in the shallow wells is soft, in the deep hard. Near Oldfield the wells average around 30 feet and yield soft water; near Sturgeon depths range from 20 to 70 feet, averaging 50 feet. The water is soft. On the terrace back of Wilcox Wharf wells are 30 to 45 feet deep. One on the bluff, belonging to T. W. Hubbard, went 12 feet through red and buff clay and 31 feet through sand, gravel, and iron crusts, with pebbles near the bottom. The water is soft and excellent for domestic use. (See analysis, table 8.)

At Eppes Island on James River, driven wells get good water from the Talbot formation at 15 feet. At and near Shirley are a considerable

number of driven wells. They are from 27 to 35 feet deep. H. S. Saunders gives the following average record for wells at Upper Shirley.

Generalized section at Upper Shirley.
(Authority, H. S. Saunders.)

Material	Thickness (Feet)	Depth (Feet)
Soil	3	3
Tough gray clay	10	13
Reddish sandy clay	15	28
Cobble bed	4	32
Coarse gravel, water-bearing	1	33

A field assay of a sample of water from a 30-foot well is given in table 7.

This well, driven some 15 years ago, is situated in a slight hollow of a terrace about 25 feet high. To guard against surface water working down along the pipe a hole 4 feet in diameter and 1 foot deep was dug about the pipe and filled with concrete. A deep well drilled for Mr. Saunders struck bed rock at 350 feet. It did not get a flow.

Near Malvern Hill post-office wells are from 20 to 70 feet deep; some of the deeper ones go down into "marsh-mud," probably fine dark clays of the Pamunkey, and obtain little water. A well at the post-office, said to be 50 feet deep, though nearly full in wet weather, is said to go dry in droughts; it evidently gets little water except what comes in near the surface. In the neighborhood are several 8-inch wells bored by an earth auger and cased with 12-inch tile. One of these owned by J. M. Gill, 70 feet deep, cost \$15 to bore. This well is said to be sunk through "marsh-mud" below the surface sands and loam. The depth from which the main supply of water comes in wet weather is uncertain. The character of the water in 1906 is indicated by the field assay in table 8.

Data regarding dug wells at a number of places in the county are presented in the accompanying table.

Details of dug wells in Charles City County.

Post-office	Depth of well (Feet)	Water bed	Quality of principal supply
Binn's Hall	12-60	Sand and marl	Hard and soft
Holderoft	13-30	Sand	.....
Oldfield	35	Sand	.....
Lent	30-75	Marl	Hard
Lame	30	Sand	Soft
Sturgeon Point	15-60	Sand and clay	Soft

Conclusions.—Good water can be had by dug, driven, and drilled wells in Charles City County. On the low ground along Chickahominy River where the shallow water is regarded with suspicion, plentiful supplies can be had from Pamunkey sands 150 to 300 feet below sea level; along the tidal portion of the river, south of Boulevard, basal sands of the Chesapeake group 100 to 150 feet below sea level, may yield small flows at elevations less than 10 feet. Along James River in the eastern half of the county good flows can be had from the Pamunkey, but heads 25 feet above river level should not be expected.

CHESTERFIELD COUNTY.

General description.—Chesterfield County, formed from Henrico County in 1748, is bounded on the north and east by James River and on the south and west by Appomattox River, but only that part of the county east of a line from Richmond to Petersburg lies within the geologic province considered in this report. In this part of the county elevations range up to 210 feet. James River and Appomattox River have cut gorges nearly 200 feet deep in what was a gently rolling plain, and tributary creeks have V-shaped valleys. Near the rivers the Columbia terraces have been largely removed, but remnants of the Sunderland and Wicomico terraces are traceable back of Manchester and along the road from Manchester to Petersburg. The Talbot terrace is nowhere conspicuous.

A gray granite, in places gneissoid, outcrops about Manchester and causes rapids in James River. It also outcrops near Ettricks on Appomattox River. The sand, sandstone, and cobble beds of the Patuxent formation are exposed in places along James River and are conspicuous on the north bank of Appomattox River. The dark green glauconitic sands of the Nanjemoy formation outcrop at Powhatan and elsewhere on Appomattox River. The sands and diatomaceous clays of the Calvert overlap the Nanjemoy, resting on that formation, the Patuxent, or the granite. The yellow, buff, and reddish loams of the Lafayette and Sunderland formations mantle the divides.

UNDERGROUND WATERS

Occurrence and character.—Ground water, stored in the coarser beds of the Lafayette and of the various Columbia formations, is the chief source of supply. Depths to the water table show the usual variations characteristic of the western edge of the Coastal Plain and range from 5 to 50 feet. The water as a rule contains little mineral matter in solution and is clear and soft.

Springs.—Chesterfield County contains many springs. As fastidious people in Richmond desired water of better appearance and greater purity than the supplies that were, until the installation of purification plants, furnished by the city waterworks, some of the owners of conveniently situated springs have sold large quantities locally, and have extended business to points outside the State. Some of the important springs are outside the Coastal Plain area, and flow from crevices in crystalline rocks; others, just within it, issue from gravelly beds in the surficial loams of the Lafayette or the Sunderland terrace. All the springs of note are mentioned here. Five of these springs have been advertised more or less extensively; the waters from several others have been sold or have been used in the manufacture of ginger ale and other sweetened beverages.

Perhaps the longest known of the springs is the Fonticello, situated in Swansboro, a suburb of Manchester, on a tract of land that is said to have been an Indian camp ground during the time of Powhatan. The spring issues from a crevice in the granite-gneiss exposed by a slight hollow in the red cobbly Lafayette loam that mantles the high ground west of Manchester for an undetermined distance. It flows from the cleft in the rock at the rate (estimated) of 18 to 19 gallons per minute and, according to the proprietor, shows no seasonal changes in flow. The water is pumped from a cement basin in the stone spring house to the bottling room. The overflow from the basin supplies a small pond. The grounds about the spring are laid out as a park. Care has been taken to exclude surface water by digging a blind ditch around three sides of the spring and laying tile drains. The source of the flow is uncertain, but the location of the spring, in a hollow on high ground, the temperature of the flow, 61° F. in October, 1906, the manner of emergence, and the character of the water indicate that the source is not deep. The water probably accumulates in the gravels of the Lafayette on the higher ground to the west and flows by connecting joints in the underlying granite to the outlet.

Fonticello Lithia water, as the output of the spring is called, is shipped in bottles and carboys. It is sold for table use and as a light bicarbonated alkaline water for disorders of the liver and kidneys.

The following analysis is recomputed from that given in circulars sent out by the proprietor.

Analysis of Fonticello Lithia water.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	46.
Silica (SiO_2)	14.
Iron (Fe)	1.6
Aluminum (Al)	0.07
Calcium (Ca)	2.0
Magnesium (Mg)	0.61
Sodium (Na)	3.5
Potassium (K)	1.5
Manganese (Mn)	trace
Lithium (Li)	0.08
Arsenic (As)	trace
Bromine (Br)	trace
Bicarbonate radicle (HCO_3)	13.
Sulphate radicle (SO_4)	2.5
Phosphate radicle (PO_4)	0.04
Chlorine (Cl)	5.4
Free carbon dioxide (c. c. per liter)	30.

Not far from the Fonticello, in Manchester, on a hillside pasture lot in the shallow valley of a small run, is another spring flowing from a cleft in granite. This spring, known as the Bellfont, has been less advertised than the Fonticello, and the water is sold chiefly for table purposes in Richmond.

The water is clear, tasteless, and odorless. There were, in 1906, no buildings on the slope above the spring for 200 yards or more, and the sanitary surroundings were good. The flow, estimated at about 20 gallons per minute, is said not to vary during the year. The only improvements at the spring at the time it was seen were a cement basin and a small frame springhouse. In essential characteristics of origin and emergence, this spring resembles the Fonticello, and the water has much the same composition. The following analysis was furnished by the former proprietor, Clarence Vaden, of Manchester.

Analysis of Bellfont Lithia water.

(W. H. Taylor, analyst.)

	Parts per 1,000,000
Total solids	44.
Silica (SiO_2)	14.
Iron (Fe)	1.0
Calcium (Ca)	1.9
Magnesium (Mg)	0.4
Sodium (Na)	3.8
Potassium (K)	2.9
Lithium (Li)	0.03
Bicarbonate radicle (HCO_3)	5.3
Sulphate radicle (SO_4)	10.
Chlorine (Cl)	5.8

About 1 mile southeast of Swansboro post-office, in a tract of land partly wooded, partly open, is a group of springs from which water has been sold from time to time. In 1905 the title passed to people who made extensive improvements with the apparent intent of having more ornate surroundings there than at any spring near Richmond. The spring-house, open at the sides, has a concrete floor, the basin is walled with slabs of white marble, and a niche of similar slabs surrounded by an ornamental iron screen is built above it. These springs, known as the Holly Lithia springs, are situated in a slight hollow of the almost level surface of the plain. The chief spring is a "boiling spring," the water rising from a bed of coarse sand, gravel, and cobbles beneath a few feet of surface soil and loam. Dug wells in the vicinity strike granite at from 5 to 30 feet below surface. The water is clear, tasteless, and odorless, and contains free carbon dioxide, bubbles of which can be seen rising in the basin. When the spring was inspected there were no dwellings nor other buildings so situated that contamination of the spring water from them was possible. The source of the water is evidently shallow, as indicated by the temperature, $62\frac{1}{2}^{\circ}$ F., in October, 1906. The present volume of flow was determined, it is said, by the improvements made; a flow sufficient to fill a 4-inch pipe was obtainable by lowering the level of the water in the spring basin 2 feet.

The output has been sold for table use almost exclusively. The following analysis, furnished by the manager, J. P. Carson, of Richmond, shows a lower mineral content than the Fonticello and Bellfont springs, but the same type of mineralization. An analysis made thirteen years before, by Chas. H. Chalkley, agrees closely with the later analysis.

Analysis of Holly Lithia water.

(Froehling & Robertson, analysts.)

	Parts per 1,000,000
Total solids	35.4
Silica (SiO_2)	11.
Iron (Fe)	0.35
Aluminum (Al)	0.8
Calcium (Ca)	1.4
Magnesium (Mg)	0.35
Barium (Ba)	0.008
Sodium (Na)	4.6
Potassium (K)	1.
Lithium (Li)	0.033
Bicarbonate radicle (HCO_3)	4.8
Sulphate radicle (SO_4)	4.3
Phosphate radicle (PO_4)	0.029
Nitrate radicle (NO_3)	2.7
Iodine (I)	trace
Chlorine (Ca)	4.4

Three miles south of Manchester, at Swineford Station, on the Atlantic Coast Line Railroad, is the spring formerly known as Swineford's spring, and now called the Lion Lithia spring. It is owned by the Virginia Lithia Springs Co. It is a boiling spring, the water rising through coarse gravels in a terrace slope west of the railroad. The flow, which is said not to vary with the seasons, is about 10 gallons per minute. Its temperature when measured, October, 2, 1906, was 63° F. The owners do not claim for the water, which is clear and bright, without color, taste, or smell, any therapeutic value, but simply state that it is a good table water. Part of the output is sold still in carboys, part is carbonated and sold in bottles, and part is used for making ginger ale. The following analysis is recomputed from one furnished by the company.

Analysis of Lion Lithia water.
(Froehling & Robertson, analysts.)

	Parts per 1,000,000
Total solids	28.1
Silica (SiO ₂)	10.
Iron (Fe)	0.11
Manganese (Mn)	0.022
Aluminum (Al)	0.18
Calcium (Ca)	1.0
Magnesium (Mg)	0.40
Lithium (Li).....	.011
Sodium (Na)	3.
Potassium (K)	1.2
Bicarbonate radicle (HCO ₃)	3.9
Phosphate radicle (PO ₄)	0.035
Sulphate radicle (SO ₄)	4.1
Arsenate radicle (AsO ₄)	0.039
Chlorine (Cl)	3.6
Iodine (I)	trace
Bromine (Br)	trace
Free carbon dioxide, 54 c. c. per liter.	

When the writer saw the spring there were no buildings above it for a considerable distance, and the chances of pollution were remote. The spring house had a tile floor, concrete walls, and an open roof. From the basin the water flowed to the bottling house, a two-story frame building 400 feet distant, which contained carbonators, automatic washing machines, etc.

Four miles west of Manchester, in a shallow ravine, is a spring with a flow of 25 to 30 gallons per minute, known as the Beaufont. It issues from a cleft in granite, and is covered by a frame spring house with cement floor. The water, which is clear and without taste or odor, had, when the

spring was visited on October 2, 1906, a temperature of 57° F. It flowed through a tile pipe line to a bottling house by the roadside, 100 yards or more from the spring. Most of the output was said to be used in making ginger ale. The following analysis, furnished by the proprietor, has been recomputed to express results in standard form.

Analysis of Beaufont Lithia water.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	63.
Silica (SiO ₂)	16.
Iron (Fe)	0.25
Aluminum (Al)	8.4
Calcium (Ca)	1.4
Magnesium (Mg)	1.0
Sodium (Na)	4.0
Potassium (K)	2.1
Manganese (Mn)	trace
Lithium (Li)	0.07
Arsenic (As)	trace
Bicarbonate radicle (HCO ₃)	15.
Sulphate radicle (SO ₄)	1.3
Phosphate radicle (PO ₄)	0.04
Chlorine (Cl)	5.2
Iodine (I)	0.06
Bromine (Br)	trace
Free carbon dioxide (CO ₂)	37 c. c. per liter

In 1906 the land about the spring was largely wood-covered; there were no dwellings near, and pollution was improbable.

Situated at Buckhead Springs Station, on the Seaboard Air Line Railroad, about 1½ mile east of Centralia, at the head of a run that empties into Proctor Creek, are the Buckhead springs, a group of three, with a total flow of about 2½ gallons per minute. The water, which comes from sandy beds in the Sunderland formation, is bright and sparkling, without taste or odor. The flow is said not to vary in volume or temperature throughout the year. The proprietor has taken strict precautions to insure the sanitary excellence of the spring surroundings. The residences and farm buildings on a small area of level ground, a remnant of a high Columbia terrace, are about 300 yards from the springs. Concrete walls and tile drains about the springs prevent the entrance of surface water. The water flows from the concrete basin at the spring-house through an enamel pipe to an enamel filling basin in the bottling house, a frame building, 60 by 20 feet, near the railroad track, where it is at once securely sealed. The output has a wide sale as a table and as a medicinal water. It con-

tains free carbon dioxide, hence is light and pleasant. The following analysis, recomputed from one furnished by the proprietor, Thos. S. Wheelwright, of Centralia, shows a low mineral content.

Analysis of Buckhead Chloride Lithia water.

(Froehling & Robertson, analysts.)

	Parts per 1,000,000
Total solids	43.
Silica (SiO ₂)	7.4
Iron (Fe)	0.1
Aluminum (Al)	0.53
Calcium (Ca)	1.4
Magnesium (Mg)	2.5
Sodium (Na)	3.6
Potassium (K)	2.3
Lithium (Li)	0.001
Manganese (Mn)	0.009
Barium (Ba)	0.02
Arsenic (As)	faint trace
Bicarbonate radicle (HCO ₃)	3.1
Sulphate radicle (SO ₄)	0.72
Nitrate radicle (NO ₃)	8.80
Phosphate radicle (PO ₄)	0.009
Chlorine (Cl)	11.
Free carbon dioxide (CO ₂), 15 c. c. per liter.	

About 5 miles south of Manchester, near Temple's station, is the Campfield spring or well. It is situated in a hollow. The water flows from a bed of gravel covered by sand and loam. The water is shipped to Richmond, Norfolk, and other points, and is sold for table and medicinal use.

The following analysis is recomputed from that supplied by the company owning the spring.

Analysis of Campfield Lithia water.

(N. B. Tucker, analyst.)

	Parts per 1,000,000
Total solids	28.
Silica (SiO ₂)	5.3
Iron (Fe)	0.3
Aluminum (Al)	0.11
Manganese (Mn)	trace
Calcium (Ca)	0.8
Magnesium (Mg)	0.9
Barium (Ba)	trace
Sodium (Na)	3.2
Potassium (K)	1.9
Lithium (Li)	0.05
Arsenic (As)	trace
Bicarbonate radicle (HCO ₃)	8.0

Analysis of Campfield Lithia water—(Continued).

	Parts per 1,000,000
Sulphate radicle (SO_4)	2.4
Phosphate radicle (PO_4)	0.03
Chlorine (Cl)	5.2
Bromine (Br)	trace
Iodine (I)	trace
Free ammonia	0.002
Albuminoid ammonia	0.009
Nitrogen as nitrates	0.0
Nitrogen as nitrites	trace (?)
Free carbon dioxide gas, 27 c. c. per liter.	

Besides these springs several others in eastern Chesterfield County are or have been of commercial importance, including the Urquhart Lithia spring, 4 miles from Richmond, and the Rocky Run south of Wiseville. A partial analysis of the water from the latter, furnished by the proprietor, David Adkin, is appended in recalculated form.

Partial analysis of Rocky Run Lithia water.

(Analyst unknown.)

	Parts per 1,000,000
Calcium (Ca)	40.
Magnesium (Mg)	0.46
Sodium (Na)	1.1
Potassium (K)	1.6
Iron (Fe)	1.1
Lithium (Li)	0.07
Carbonate radicle (CO_3)	1.2
Sulphate radicle (SO_4)	6.3

In the southern part of Chesterfield County are several springs from which water is or has been sold in Petersburg. One of these, the Patrol Oaks Mineral spring, three-quarters of a mile northeast of Ettricks, is a well rather than a spring. The water is clear, tasteless, and odorless; the flow is about 6 gallons per minute.

Another spring just north of the Powhatan highway bridge across Appomattox River is owned by a company and was once an important source of drinking water in the city of Petersburg. It is known as the Aqueduct spring. The water is still sold in the city, being delivered to houses at a nominal charge, and is the chief drinking water in Powhatan.

There are several springs along the valley side near Powhatan, some of the water coming from the Pamunkey (the contact of the basal pebble bed of this formation with dark clays of the Potomac being exposed just below the springs), and some of the water coming from under the Columbia loam which hides the older formations. The water is tasteless and odor-

less, clear and soft, and the slope above the springs has been so sparsely inhabited that the possible contamination of the sources has not called for investigation.

Wells.—Dug wells are almost the sole source of underground water for domestic supply. There are few drilled wells. The large manufacturing concerns and the railroad yards in Manchester either use city water or pump their own supplies from James River.

LOCAL SUPPLIES

Manchester, now a part of Richmond, owned its waterworks in 1906 and distributed filtered James River water. In the outskirts of the city, particularly to the west, are many shallow dug wells. The suburb of Swansboro, for instance, with a population of several thousand people, had no public supply system in 1906. The wells were dug through Lafayette cobble loams and decomposed granite, some obtaining water from the Lafayette and some from the granite. In places where firm granite comes near the surface more or less blasting has been done, usually with indifferent success. Where the cover of loam is thin, dug wells in such a thickly settled area are particularly liable to pollution; where 25 feet of loam, sand, and rotten granite are found above water, there is less danger; but wells should not under any circumstances be located within 75 feet of cesspools, privies, and other sources of contamination, and should be properly protected. In Manchester the local authorities have been closing dug wells as city service is extended.

At Bermuda Hundred on the bank of James River dug wells average 15 feet deep; the supply is not considered as satisfactory as that from springs, of which there are several along the foot of the low bluff facing the river. One of these, on property of the Farmville & Powhatan Railroad, has a bold flow of soft water, sufficient for the needs of several families.

At Centralia dug wells go down 18 to 20 feet, and obtain soft water from Columbia sands and clays.

There are in Chester about 50 dug wells 25 to 40 feet deep which get water from Columbia sands. Neither at Centralia nor Chester do wells go to hard rock.

At Etricks, just across Appomattox River from Petersburg, dug wells are 12 to 45 feet deep, averaging 20 feet. They are not sunk to rock, but get water of varying quality, mostly soft, from beds in the Columbia.

Dug wells in Powhatan are sunk in Potomac and Columbia sands and gravels. They are about 20 feet deep, and some yield water of

suspicious quality. Much of the drinking water used is taken from the Aqueduct Spring, previously mentioned.

Conclusions.—Satisfactory supplies for isolated residences and farm buildings can be had from dug wells. In thickly settled areas water much less liable to pollution can be had from drilled wells. Owing to the dissection of the Coastal Plain formations by the gorge of James River, flowing wells are not to be expected.

DINWIDDIE COUNTY.

General description.—Dinwiddie County, formed in 1752 from Prince George County, lies between Appomattox River and Nottoway River. Only a narrow strip along the east line of the county, which contains the city of Petersburg, is included in the Coastal Plain.

Most of this area has an elevation of more than 150 feet, and is included within the Lafayette and Sunderland terraces. Small patches of the Wicomico and lower terraces are found along Appomattox River near Petersburg. From an elevation of nearly 300 feet within a few miles of Petersburg there is an abrupt descent north to Lieutenant Run and Appomattox River, and a gentle slope southeastward. The southward-flowing streams which head in the divide, tributaries of Blackwater River, flow through swampy valleys.

Geology.—Crystalline rocks underlie the Coastal Plain section of the county at no great depth. Potomac, Pamunkey, and Chesapeake beds are all exposed in the immediate vicinity of Petersburg, but elsewhere are usually hidden by the Lafayette or the Columbia formations. The three, however, may be seen along Livetenant Run. Potomac arkosic sands and cobble beds are exposed near the mouth of the run at the crossing of the Norfolk & Western Railroad; Pamunkey greensands are visible at the east end of the dam at the city pumping station; and light-colored diatomaceous clays and dark greenish sandy clays of the Chesapeake, full of clam and scallop shells, are to be seen along the run and in its bed as far west as the Seaboard Air Line Railroad. Both the Potomac and Pamunkey are barely thicker than feather edges near Petersburg. The Chesapeake overlaps them and may have an extreme thickness of more than 100 feet at the eastern end of the county.

UNDERGROUND WATERS.

Occurrence and character.—All the Coastal Plain formations carry ground water, but the depths to the water table and the character of the

water vary greatly. The chief sources of supply are the Lafayette and Sunderland formations, though a considerable number of wells are sunk in the Talbot and Patuxent sands and gravels near Appomattox River.

Springs.—There are numerous springs along hillsides and stream valleys, but they are usually small and of little importance, except for watering stock. No mineral springs from which water is shipped on a commercial scale are reported.

Wells.—Dug wells are the principal source of supply. Throughout the rural districts wood curbing is commonly used, but near Petersburg many dug wells are curbed with brick or stone. There are very few deep drilled wells in the Coastal Plain portion of the county.

LOCAL SUPPLIES.

The public supply system of the city of Petersburg gets water from Livetenant Run. There are, in the outskirts of the city, many shallow dug wells that vary greatly in depth and in probable freedom from pollution. Some dug wells in the city are used for boiler supply and other industrial purposes.

The only deep wells reported are those of J. B. Worth & Co., near the river. They are 100 and 150 feet deep, respectively, and yield under a pump 50 gallons of water per minute, which is used for condensing because of its temperature, 59° F.

Near Rowanta wells are 20 to 60 feet deep, most of them being about 25 feet. The deeper wells in this part of the county go through the Sunderland formation and get water, which is apt to be hard, from shell marl beds in the Chesapeake.

Conclusions.—In the rural districts dug wells not near sources of pollution, if properly protected against the entrance of surface impurities, will yield satisfactory supplies. In the city of Petersburg and its more thickly settled suburbs drilled wells are preferable for sanitary reasons. Flowing wells are not to be expected anywhere in the county.

ELIZABETH CITY COUNTY.

General description.—Elizabeth City County, formed in 1634 as one of the eight original shires of the Virginia colony, covers the tip of the peninsula, the strip of land between James and York rivers. The county contains the towns of Hampton and Phœbus, and the military post of Fort Monroe, near Old Point Comfort. At Old Point Comfort is the

Chamberlain Hotel, a famous health and pleasure resort; near Phœbus is a National Soldiers' Home; and at Hampton is the Hampton Normal and Agricultural Institute.

The county has a flat ill-drained surface, most of it being within the area covered by the lowest of the Columbia terraces, the Talbot. Elevations of about 30 feet are found in the low terrace along the Warwick County line. This plain grades very gently east to the salt marshes and mud flats of the shores.

Geology.—The yellow, buff, and gray loams and sands of the Talbot cover practically the entire surface of the county. The maximum thickness of the Talbot on the east side of the county is uncertain, but may amount to 50 feet. Below the Columbia lie Chesapeake, Pamunkey, Upper Cretaceous, and Potomac beds. The base of the Chesapeake beds on the east side of the county is about 600 feet below sea level. Beneath are about 150 feet of Pamunkey, 500 feet of Upper Cretaceous, and 900 feet of Potomac beds, the crystalline rocks lying perhaps 2,250 feet below sea level.

UNDERGROUND WATERS.

Distribution and quality.—The water table lies near the surface, and dug and driven wells get water at from 5 to 15 feet. The quality of the ground water is variable. Along the shores wells are liable to become salty under heavy pumping, and where the surface loams and sands are thin, wells go down into shell beds which yield hard water. The Chesapeake sands are uncertain water-bearers. The sands are local and seldom yield free flows. The water is iron-bearing in the upper beds and brackish in the deeper ones.

Springs.—There are no springs of commercial importance in the county. Most of the so-called springs are very shallow wells, dug in hollows where the water table is but a foot or two below the surface; many used for stock and household purposes have unsanitary surroundings and are liable to be badly polluted.

Wells.—Dug wells are mostly used, but there are many driven wells in the county. The deep drilled wells have been mentioned in the discussion of the Norfolk-Newport News area on pages 97-116.

LOCAL SUPPLIES.

Hampton obtains water from the Newport News Light & Water Co., a corporation that supplies surface water from a watershed in Warwick and

York counties to Newport News, Phœbus, the National Soldiers' Home, Hampton Normal and Collegiate Institute, and Fort Monroe. Within the corporate limits of Hampton are perhaps 3,000 persons, of whom fully one-half used this water in 1906. Another company, the Peninsula Pure Water Co., proposed to supply Hampton, Phœbus, Old Point Comfort, and the lower part of the county generally. The water was to come from ponds near Bethel, 9 miles from Hampton.

In the suburbs of Hampton about nine-tenths of the population use driven wells which get water at 10 to 12 feet in blue and white sands and marls. Much of the well water in Hampton is too hard for laundry use, while that near the shore is brackish; hence there are many cisterns. Near the Courthouse a well, elevation about 5 feet above mean high tide, dug for fire protection, is 25 feet in diameter and 22 feet deep; it passed through marl for 16 feet. It is now used for watering horses.

In the suburbs of Hampton some dug wells were still used as a source of drinking water in 1906, but their use was condemned by local health officials.

At Hampton Normal and Collegiate Institute most of the water used is supplied by the Newport News Co. There are several dug wells 10 to 15 feet deep, cased with 16-inch tile. The elevation of the Institute grounds, which border a tidal inlet, does not average over 5 feet; hence the well water has a high chlorine content. It is examined frequently for indication of possible contamination. The following determinations, made by W. S. Sweetser of the Institute, show the character of water from the better wells near the shores of lower Elizabeth City County.

*Analyses of water from wells on grounds of Hampton Normal and
Agricultural Institute.*

(W. S. Sweetser, analyst.)

Location of well	Parts per 1,000,000	
	Chlorine	Total solids
Machine shop	59.4	265.0
Hospital	45.3	373.0
Trade school	28.8	401.0 ^a
Whittier School	24.7	—

A well just outside the Institute grounds, close to the shore, gave water which contained 111 parts of chlorine per 1,000,000, but this water was pronounced dangerous.

^aHigh in nitrates; not used.

A 12-foot well dug on the Hemenway farm 6 miles from Hampton on Back River obtains water from a marl bed. The well is about 500 feet from salt water; the elevation is 6 feet, and depth to water 3 to 6 feet. The following partial analysis was made by the chemical laboratory of the Institute.

Analysis of water from well on Hemenway farm.

(W. S. Sweetser, analyst.)

	Parts per 1,000,000
Calcium (Ca)	188.
Magnesium (Mg)	16.5
Sulphates as SO ₄	32.
Total hardness, as CaCO ₃	38.4
Chlorine	113.

The Soldiers' Home, officially designated the Southern Branch of the National Home for Disabled Volunteer Soldiers, is just outside the municipal limits of Phoebus. Over nine-tenths of the water used is obtained from the Newport News Co. A few driven wells about the grounds furnish drinking water. Cistern water is used for flushing, and salt water for flushing and for fire protection.

In Phoebus there are many driven wells 13 to 15 feet deep which get water in Columbia gravels, under quicksand and yellow loam. The water is generally hard, but is used for all household purposes. In 1906 probably three-fourths of the population used such wells, the remainder taking Newport News water.

The Hotel Chamberlain uses some 60,000 gallons of water daily, about half of which is furnished by the Newport News Co., and half obtained from two dug wells 10 feet in diameter and 14 feet deep just outside the municipal limits of Phoebus on the Soldiers' Home grounds. The elevation of the surface at the wells is 8 feet above mean high tide. The wells are bricked, and the water rises from sands of the Talbot formation, normal water level being about that of mean high tide. Either well can be pumped dry in two hours by a 4 by 6 inch duplex steam pump running 60 strokes per minute, and to get the most water the wells are pumped together about 8 hours out of the 24. The wells were dug for the old Hygeia Hotel, which had to get water by boat from Norfolk. The well water, though slightly hard, is used as it comes from the well for all purposes except drinking; for drinking it is distilled. The flow from the deep artesian well at the hotel (see page 105) is used for flushing only.

At Fort Monroe three attempts to get good water by deep drilling ended with the well sunk to granite in 1902 (see page 100). About 1894 the

Government drove a series of wells on the mainland from which water was pumped to the fort by a pipe under the creek. The supply was satisfactory for a while, but other wells were driven nearby the city of Phœbus, and under heavy pumping the wells all became salty and were abandoned. In 1906, the post used for all purposes about 300,000 gallons of fresh water daily, supplied by the Newport News Co. Salt water is used for fire protection.

Conclusions.—Dug wells in places where the water table lies as near the surface as in Hampton County are peculiarly liable to be polluted, and their use on landholdings as small as the average house lot is altogether objectionable. Driven wells that go at least 10 feet below the water table are much to be preferred. The prospects for getting water of good quality by deep drilled wells in the eastern part of the county are decidedly unfavorable.

ESSEX COUNTY.

General description.—Essex County, formed in 1692 from Rappahannock County, lies on the south side of Rappahannock River, in the western part of the Coastal Plain.

Topographically the county resembles many other counties of the Coastal Plain. A high terrace, the Sunderland, with a slightly rolling surface, forms the divide between Rappahannock and Mattaponi rivers. Near Rappahannock River this terrace is deeply cut by creek valleys. Where the Wicomico terrace is missing bold headlands of the Sunderland overlook the river, and are noticeable features of the topography. The height of the Sunderland plain at the northwest end of the county is about 180 feet; at the southeast end about 150 feet.

Underlying the loams and gravelly beds of the Columbia terraces, the sandy and diatomaceous clays, clayey sands, and shell beds of the Chesapeake group can be seen in many road cuts. The basal part of the Chesapeake carries many indurated layers from a few inches to a few feet thick that are a source of trouble to well drillers. The dark greensand marls of the Pamunkey underlie the Chesapeake, but are not exposed at the surface anywhere in the county. The top of the Pamunkey is near sea level at the west end of the county, and 300 feet below at the east end.

UNDERGROUND WATERS.

Character and extent.—The chief sources of ground water are the sands of the Sunderland and Talbot terraces. Wells in headlands of the Sunder-

land formation, near Caret, Upper Mount Landing, and Dunnsville, are 50 to 60 feet deep, while back from the valley front and away from stream gulleys, as at Center Cross, are wells 15 feet deep or even less. On the low terraces along Rappahannock River dug wells are 10 to 25 feet deep, and in the lowlands at the head of Pianketank River are even shallower. The quality of the well waters varies greatly. The waters from the Columbia formations are generally soft and low in iron, but wells that strike the Chesapeake shell marls, either near surface or beneath the Columbia, get hard water.

Springs.—Springs are abundant, but only a small proportion are used for household supply, and none is of commercial importance. Practically all the springs are of the usual Coastal Plain type and most of them flow from the contact between the Chesapeake sandy clays and the clean, sharp sands of the Columbia formations.

None of the springs is now of commercial importance, though two have attracted attention. One of these, near Dunbrooke, is situated in a little hollow. Iron crusts lie about the spring and the water rises from a bed of sand in the Sunderland formation. The water is perfectly clear when fresh, but contains iron enough to leave a slightly yellow deposit about the spring. It has some local repute for medicinal value, but lack of convenient transportation facilities has retarded efforts to put it on the market.

Two springs, one of which was formerly a resort, are on land near Meade, owned by Charles C. Tombs, and now used as a camp-meeting ground. One is called a sulphur, the other a lithia spring, but both are of the same type and the waters are much alike. Meade camp-meeting ground is on the Sunderland plain in a grove of young hardwood. Spring-fed tributaries of a creek are eating into the plain, and just south of the camp-meeting grounds one of these has made a gulley some 40 feet deep. At the head of the gulley is the so-called lithia spring. It trickles from between dark greenish Chesapeake clay and overlying gray sands and iron crusts at the base of the Sunderland formation. The flow is not large, possibly two gallons per minute. In 1906, a shallow basin, 5 feet long, with wood sides, was the only improvement at the spring. The water is soft, contains a little iron, and is clear and odorless, with a very slight "iron" taste. The thickness of the overlying loams, the excellent surface drainage, the short time the grounds are frequented, and the sanitary precautions taken should keep the spring from becoming polluted.

The other spring, situated at the foot of a slope on the west side of the camp-meeting grounds, is now known as the iron spring but was called a

sulphur spring. It flows from sands beneath a ledge of iron-stone near the base of the Sunderland formation. The water is perfectly clear and colorless in the basin, but contains a little iron, as is shown by yellow stains on the wood trough. It is said to have had a decided "sulphur odor," but this is now barely perceptible. Sixty years or more ago this spring was made a resort, and a hotel erected. The improvements have disappeared, and, though the water has a considerable reputation as a remedy for various complaints, it is not sold, though more or less is taken away by visitors. Field assays of the water of the two springs are given in table 6.

Other springs of note from their size, quality of water, or improvements, are owned by Armistead Ransome, of Dunnsville; J. H. Allen, of Layton; and Clayton Stafford, of Bowler's Wharf. Mr. Ransome's spring is said to flow 30 gallons per minute of soft water. The water from Mr. Allen's spring was once shipped to Washington, D. C., for use by a druggist. Mr. Stafford's spring flows 8 gallons per minute of clear water from the base of the Sunderland scarp. It is equipped with a hydraulic ram for household supply.

Wells.—Dug wells are the chief source of supply. In the Sunderland formation they are usually curbed with wood for 16 feet at the bottom; in the Talbot they are often curbed to the top.

Wells drilled deep enough to reach the water-bearing sands interstratified with rocky layers at the base of the Chesapeake are numerous along the Rappahannock River, there being fully 30 in the town of Tappahannock alone. They are mostly bored to get flows sufficient for domestic use, hence are of small diameter, usually $1\frac{1}{2}$ inches. The reported depths vary from 250 to 270 feet below mean high tide; the reported heads vary from 10 to 30 feet above it.

LOCAL SUPPLIES.

At Tappahannock many dug wells get hard water at 12 to 15 feet. Nearly all the water now used for domestic purposes is obtained from flowing wells that strike sands underlying "rocks" at the base of the Calvert formation at a depth of 270 feet below mean high tide. The wells are mostly $1\frac{1}{2}$ inches in diameter with a 2-inch casing driven through the Columbia sands and loams into the Chesapeake clays; the later wells frequently have a $\frac{3}{4}$ -inch pipe to the bottom. The elevation of the terrace on which the town stands is 28 feet, but the flows, which vary with the tide, are usually small, from 1 to 2 gallons per minute. At no place in Tidewater Virginia, however, is there more economy in the use of water. Some wells supply two and even three houses, the water being piped in some instances several hundred feet, either directly from the well or from a tank

at the well. There is no public supply system, but, as a safeguard in case of fire, a number of masonry tanks have been constructed by the town which are kept full by the overflow of certain wells.

The water is clear, and, though containing more lime than some Chesapeake flows, it is soft, adapted to all household purposes, and an admirable table water; a slight "sulphur" odor quickly disappears when the water stands in an open vessel. The temperature at the well mouth averages 61° F. A canning factory and a large pickling house use the water.

There are about 30 wells in or near the town, and, according to the driller who has sunk most of them, the succession of materials is as follows:

Generalized section at Tappahannock.

(Authority, O. D. Hale, driller.)

Material	Thickness (Feet)	Depth (Feet)
Sand and light clay	65	65
Blue clay with rock layers ½ inch to 6 inches thick; a little water at 135 feet	135	180
Mixed clay and sand	93	273
Thin crust of shell rock; variegated sand below; water-bearing	1	274

A noteworthy feature of the Tappahannock wells is the cypress "logs" which drillers report at about 60 feet; some of them, said to be several feet thick, cause much trouble in drilling.

Of the individual wells, the one at the pickle house of Donaldson & Shultz has the freest flow; it is on the river edge, and the mouth of the well is only 4 feet above tide. The flow in 1906 was 5½ gallons per minute, but is said to have been 12 gallons. Another good well is at the residence of B. P. Brockenborough on the edge of the terrace overlooking the river. It is cased with 2-inch pipe to the bottom, 272 feet, and has a 3-inch casing down 150 feet. The water, which is said to rise 16 feet above surface and more than 30 feet above mean high tide, is piped to the residence.

The following partial analysis of water from the well of R. T. Cauthorn shows how free from organic matter is the water from the principal water bed. Field assays of water from wells at Tappahannock and other places are given in table 9.

Partial analysis of water from well of R. T. Cauthorn, Tappahannock.

(G. H. Lehmann, analyst.)

	Parts per 1,000,000
Total solids	494.
Volatile matter	48.
Chlorine	1.95

*Partial analysis of water from well of R. T. Cauthorn, Tappahannock—
(Continued).*

	Parts per 1,000,000
Nitrogen, as free ammonia	0.
Nitrogen, as albuminoid ammonia.....	0.
Nitrogen, as nitrates	0.
Nitrogen, as nitrites	0.
Sulphates, as SO ₄	34.
Hardness	25.

Just north of Tappahannock, R. B. Brockenborough has four artesian wells at his large stock farm. One of these, at the manager's home, is used for domestic purposes; the other three, at barns and outbuildings, are for watering stock. In volume of flow and quality of water the wells resemble those in the village of Tappahannock. Up the river there are wells at the farms of J. P. Taliaferro and C. B. Mallory, southeast of Caret, and still farther upstream are those of Joseph Baker, J. H. C. Beverly, Mrs. M. S. Sale, and H. K. Baylor, all of which tap the same water bed.

West and south of Tappahannock artesian wells on Hoskins and Piscataquis creeks and along the Rappahannock include those of John Bradley, G. F. Croxton, and J. L. Kriete.

The first important group of wells down the river is at Ware's Wharf, where there are 5 which, though shallower than those at Tappahannock, going to an average depth of 185 feet below sea level, yield water of the same general character. The flows at individual wells vary with the tide, but range from $\frac{1}{2}$ to 2 gallons per minute, with heads as high as 16 feet above sea level. The following record of one well was given from memory.

Record of well of R. L. Ware estate, Ware's Wharf.

(Authority, R. L. Ware.)

Material	Thickness (Feet)	Depth (Feet)
Surface soil, clay and sand	30	30
Marl	140	170
Rocks	35	205

Another important group of wells is at Bowler's Wharf, 3 miles below Ware's Wharf. Here 10 wells get water from varying depths, the main flows being at about 165 to 180 feet below mean high tide. The water-bearing sand contains many rocky streaks, and the flows of nearby wells differ, the distribution of these impervious layers being a determining factor. Above the main flow is a weak one at about 130 feet, and below the main flow is another at about 240 feet. The record of the well drilled at the steamboat wharf ran about as follows:

Record of well of Garrett & Hunt, Bowler's Wharf.

(Authority, I. W. Hunt, owner.)

Material	Thickness (Feet)	Depth (Feet)
Water	10	10
Sand and gravel	15	25
Blue clay with shells	123	148
Sand	1	149
Strata of rock 1 to 9 inches thick and 6 inches to 4 feet apart; blue mud and shells, gray and red sand, and gravel between rocks; increased flow with each sand bed penetrated.....	18	167

This well, situated at an oyster house on the end of the wharf, flows a full 2-inch stream, 30 gallons per minute, at an elevation of about 5 feet above mean high tide and has a head of over 15 feet. It is one of the finest wells on Rappahannock River. In 1906, the flow was used as a table water on the steamboats plying between Fredericksburg and Baltimore, and for washing oysters.

Another fine well, at the canning factory of the Claybrook & Neale Packing Co., has a larger flow than that of Garrett & Hunt, namely, 45 to 50 gallons per minute at 5 feet elevation. Another well, with a flow of 17 gallons per minute at an elevation of 10 feet, is used by C. P. Garrett.

On the river shore 3 miles south of Bowler's Wharf, two wells have been drilled near a canning factory owned by Latimer Kriete to depths of 190 and 195 feet, respectively, and reach the same horizon as the wells at the wharf. One of the wells has a head of 30 feet above mean high tide, and flows 32 gallons at an elevation of 4 feet; the flow of the other was reduced by an accident in drilling. In a boiler the water has a tendency to foam and is said to form a white scale.

Just below Mr. Kriete's house, which stands on a projecting headland of the Sunderland terrace, a well was drilled to a depth of 300 feet, but, as the surface elevation is fully 65 feet, no flow was obtained.

Near Jones Point, 7 miles below Bowler's Wharf, are several flowing wells. One of these, owned by Garrett & Taylor, is $1\frac{1}{2}$ inches in diameter and 221 feet deep. It flows 20 gallons per minute at 5 feet above mean high tide. The following record is reported:

Record of well of Garrett & Taylor on Jones Point, northwest of Butylo.
(Authority, I. W. Hunt, driller.)

Material	Thickness (Feet)	Depth (Feet)
Sand and clay	15	15
Gravel, surface water	3	18
Blue mud with beds of marl	107	125
Alternating layers of sand and rock; 22 rocks in all; first flow of water at 127 feet; main flow at 181 feet.....	106	231

Of the villages in the country using dug wells as sources of supply, Center Cross is one of the most important. The wells are sunk in the Sunderland formation to depths of 15 to 35 feet, and as a rule yield soft water. Information regarding dug wells at various places in the county is given in the following table:

Details of dug wells in Essex County.

Location	Depth of well (Feet)	Water bed	Quality of water
Banks	20-60	.....	Soft
Dunnsville	32-80	.....	Soft, hard
Caret	25-48	.....	.....
Center Cross	12-60	Loam and sand	Soft
Howertons	12-30	.....	.....
Laytons	15-30	Sand	.....
Lloyds	25-30	.....	.....
Loretto	18-20	.....	Soft
Mount Landing	10-60	Sand	.....
Meade	20-50	.....	.....
Pedro	20-50	Sand	.....

Conclusions.—Dug wells on high ground, if precautions are taken in locating and protecting them against the entrance of surface impurities, will yield satisfactory supplies. On the low terrace along Rappahannock River and its tributaries, flows of excellent water for domestic use can be had at comparatively low cost. There is a possibility of getting flows along Pianketank River, but the chances for flows at over 30 feet above sea level are poor. Flows of good quality and of equal or larger volume can undoubtedly be had from sands below those already developed.

FAIRFAX COUNTY.

General description.—Fairfax County, formed in 1742 from Prince William County, is in the northern part of the State, and is bounded on the east by Potomac River. The Coastal Plain portion along Potomac

River is about 16 miles long, but nowhere more than 6 miles wide. In it is Mount Vernon, the residence of General Washington.

The topography is rolling and broken as a whole. Along Potomac River are some nearly level stretches on low terraces, with elevations of 20 to 60 feet. Along the deeply scored sides of the Potomac valley, at higher elevations, are remnants of older terraces. An inlier of the Lafayette formation covers a considerable area north of Weddeburn and Dunn Loring, and caps the highest point in the county, Peach Grove Hill, at an elevation of 500 feet. The principal creeks in the Coastal Plain section of the county, Cameron Run, Accotink Creek, and Pohick Creek, are 8 to 15 miles long.

Back from the river the crystalline rocks are exposed in creek beds and on the valley slopes above. Near the river the sands, gravel beds, and clays of the Potomac group outcrop. The contact between the crystalline bed rock and the Potomac dips east fully 40 feet to the mile, so that at Mount Vernon the Potomac has a thickness of 525 feet. The Patuxent formation with its characteristic arkosic sands and dark clays includes fully 350 feet of the total thickness of the Potomac.

The maximum thickness of the Lafayette formation on the inlier north of Dunn Loring may be 40 feet. The Columbia formations vary in thickness from a thin edge to more than 35 feet.

UNDERGROUND WATERS.

Occurrence and character.—The decayed top of the crystalline rocks and the Potomac, Lafayette, and Columbia beds above contain ground water. The depth to water and the quality of the supplies vary greatly with the location of the wells and the character of the formations penetrated. One well may find plenty of water in Columbia gravel within a few feet of the surface, while another on a nearby slope, where the Columbia beds have been removed, may have to go deep into the Potomac beds or the granite to get a sufficient supply.

As in other counties along the "fall line," the water from the Lafayette and the higher-lying formations of the Columbia group is generally soft and slightly mineralized. On the lowest of the Columbia terraces the ground water in some places contains much iron; in others, it is excellent. The Potomac sands contain much water, but the sands that yield water freely are of irregular extent and the quality of the water varies. On high ground the crystalline rocks as a rule carry good water.

Springs.—Springs are numerous, but most of them are of small flow; only a few are of fair size. The waters are usually soft and pure and are often used for household purposes. From a few springs water has been shipped, but none is now of commercial importance.

Wells.—Dug wells, the main source of domestic supply, are frequently lined with stone and brick. Some are cased with large tile. Depths to water and the yield vary widely. Many wells are so situated and protected that there is little chance of pollution; others, particularly some on level stretches of the lowest terrace, have insanitary surroundings. Nearly all the drilled wells are 6 inches in diameter. Those on the lowest terrace get water from sands in the Patapsco or Patuxent formations of the Potomac group. Those on the high ground go into decayed or solid granite or gneiss. On the high ground no wells over 200 feet deep have been reported, but there are several of greater depth near Potomac River. The yield of the deep wells on high ground is seldom large, but nearly always sufficient for domestic purposes. Of the wells sunk on low ground to the Patuxent sands some yield large supplies, others only enough for the needs of a household of average size.

LOCAL SUPPLIES.

At the military post of Fort Hunt on Potomac River, 8 miles below Alexandria, all the water used is obtained from an 8-inch well sunk to a 13-foot bed of white sand in the Potomac group, 202 to 215 feet below the level of the terrace. The following record was obtained by Darton:

Record of well at Fort Hunt.
(Authority, W. C. Miller, driller.)

Material	Thickness (Feet)	Depth (Feet)
Yellow clay	24	24
Blue clay	15	39
Heavy sand and gravel, with little water	3	42
Red, blue, and yellow clays; streak of sandy blue clay with a little water at 122 feet	80	122
Red and blue clay	80	202
Coarse white sand with large supply of good water rising within 17 feet of surface.....	202	215

Pumping 53 gallons per minute lowers the water 15 feet. The water is pumped by an air lift to a cistern and is forced thence by a steam pump to a tank on a steel tower. The water is colorless, tasteless, and odorless. According to W. New, of the U. S. Surgeon-General's Office, the mineral

matter is chiefly sodium sulphate with traces of calcium, magnesium, and iron salts. A partial analysis showed 342 parts of total solids and 5.14 parts of chlorine per million of water.

About a mile southwest of Fort Hunt, at the residence of Dr. Bliss, is a 65-foot drilled well that gets soft but slightly iron-bearing water from a Potomac sand or gravel bed. Dug wells in the vicinity get water from Columbia loams and sands at depths of from 15 to 25 feet.

A mile northwest of Fort Hunt, at Riverside Park near the mouth of Little Hunting Creek, on property owned by the Riverside Brick Co., are two 6-inch wells which get water from Potomac beds. They are said to be over 100 feet deep. Neither gives a flow, the elevation of the surface being about 20 feet. Each affords a fair supply of good, though slightly iron-bearing water. Near Hunters station, on the Washington, Alexandria & Mount Vernon Railroad, a drilled well gets good water from a bed of white Potomac sand at 165 feet.

At Arcturus station, on the same road, household supplies are obtained from dug wells. The deepest of these, about 30 feet, owned by H. C. Pilling, strikes a bed of sand and mud containing "logs," and yields water high in iron. A gasoline engine pumps the water to a tank.

At Mount Vernon water for domestic purposes is obtained from an 8-inch artesian well 525 feet deep. The well is near the edge of the river, the well mouth being about 7 feet above high tide level. Little water was found in the basal beds of the Patuxent formation, and the casing was pulled back. The present supply, which rises within 6 feet of the surface, its level fluctuating with the tide, comes from a sand and gravel bed at 345 feet. The following log, kept by W. H. K. Shannahan, the driller, was furnished by William Archer, of Mount Vernon.

Record of well at Mount Vernon.

(Authority, J. H. K. Shannahan, driller.)

Material	Thickness (Feet)	Depth (Feet)
Blue and red clay	10	10
Gray clay	15	25
Hard green and blue clay.....	25	50
Hard green, blue, and brown clay.....	25	75
Sandy brown clay	25	100
Coarse green water-bearing sand; bad water, has the odor of marsh water, very unpleasant	25	125
Brown and green clay and gray sandy clay	25	150
Marsh clay	50	200
Very hard and dry brown, green and blue clays.....	100	300
Light green sandy clay	25	325
Light green sand, water-bearing below 340 feet, source of present supply	25	350
Clays	165	515
Sand, little or no water, and that sulphur-bearing.....	10	525
Bed rock	525	

The water supply is good. A steam pump lifting 50 gallons per minute from the well to a tank on top of the bluff, 175 feet, lowers the water about 9 feet. The water is soft and works nicely in a boiler, making little scale.

Water for washing, flushing, and greenhouse use at Mount Vernon is obtained from springs developed by drains along the face of the river bluff. The mode of development is described on page 62.

On Sandy Point a deep well was sunk for H. L. Cranford some years ago. The following record has been published:^a

Record of well on Sandy Point, 2 miles southwest of Gunston.

(Authority, L. W. Shepard, driller.)

Material	Thickness (Feet)	Depth (Feet)
White and yellow clay	20	20
Very soft blue swamp muck.....	80	100
Gravel and sand; water	15	115
Clay	15	130
Gravel and sand; water	10	140
Clay	10	150
Fine sand and clay; water.....	60	210
Clay	20	230
Fine sand and clay	25	255
Clay	9	264
Small pebbles and lignite	6	270
Clay	15	285
Soft rock; no water	5	290
Rock	270	560

The well was dynamited at 265 feet. The water from this point rose within 24 feet of the surface or about mean high tide level, and, according to the driller, showed tidal fluctuations of 3 feet.

Near the village of Accotink dug wells vary from 15 to 90 feet in depth, according to location, and get water of varying quality from Columbia and Potomac sands and pebble beds. The deepest of these dug wells is owned by J. P. H. Mason. It is on a hill $1\frac{1}{2}$ miles north of Accotink and about 180 feet above tide level. The well, which is 91 feet deep, went through these materials.

^aDarton, N. H., Artesian water prospects of the Atlantic Coastal Plain, Bull. U. S. Geol. Survey No. 138, p. 178.

Record of dug well one and one-half miles north of Accotink.
(Authority, J. P. H. Mason, owner.)

Material	Thickness (Feet)	Depth (Feet)
Very hard red gravel	18	18
"Fullers earth"	10	28
Light bluish sandy clay	16	44
White clay and sand, a little water.....	5	49
Light bluish sandy clay; water at 88 feet.....	42	91

Another well, 300 yards east of this, found a little water at 56 feet and no water below for 60 feet.

On the inlier of Lafayette formation that extends from near Dunn Loring to Peach Grove and Freedom Hill, dug wells are from 20 to 40 feet deep. The water, which is generally soft, is obtained from the Lafayette, and where that formation is thin, from decomposed crystalline rock. The deepest well reported in this section, 130 feet, is that of R. H. Watts, about 1½ miles east of Freedom Hill. It is said to have been drilled through clay and gravel and to have struck no rock. The first water was struck at 30 feet, but the main supply, about 10 gallons a minute, comes from 120 feet.

Near Springman dug wells are 20 to 60 feet deep, about 50 feet being the most common depth and the one at which most water is obtained. At Pohick, Springman post-office, a well at the Methodist Church is 80 feet deep, obtaining water at 70 feet, but the church is on top of a hill.

The town of Falls Church had no public water supply system in 1906. The inhabitants relied chiefly on dug wells 10 to 35 feet, most of which yielded soft water.

At West Falls Church a 120-foot well, drilled for the Washington, Alexandria & Falls Church electric road, obtained in "granite" an irony water which is not used.

Particulars regarding dug wells at some villages are given below:

Details of dug wells in Fairfax County.

Location	Depth (Feet)	Water bed	Quality of water
Accotink	25-91	Sand and clay	Hard
Dunn Loring	20-65	.....	Soft
New Alexandria	10-20	Sand and loam	Soft
Lorton Valley	20-50	Sand and gravel	Soft

Conclusions.—Good water can be had in the Coastal Plain portion of Fairfax County by both dug and drilled wells. At most places the former will furnish ample supplies for ordinary purposes, and if properly located and cased will be safe. Drilled wells near Potomac River will find good supplies in the Patuxent sands. Flowing wells, except at the water edge, are not to be expected.

GLOUCESTER COUNTY.

General description.—Gloucester County, formed from York County in 1861, lies between York River and Pianketank River.

Topographically the county is one of the most interesting in Tidewater Virginia. Part of the surface is included in the Sunderland terrace. The highest points in this terrace, about 125 feet, are in the northwest corner of the county; the lowest points have an elevation of 100 feet. The Talbot^a terrace covers most of a triangular area between Severn River, Mobjack Bay, York River, and a line from Gloucester Point past Hayes' Store and Roanes to Pianketank River; this line follows a sharply defined scarp, the most marked and unmistakable terrace scarp in the Virginia Coastal Plain. From the foot of this scarp at an elevation of about 25 feet the Talbot terrace slopes very gently eastward to sea level, fading away in strips of salt marsh and wet ground.

Geology.—The Columbia formations are prevailingly loamy at top and sandy below; along York River large ice-borne boulders are found in the lower formations. Beneath the Columbia are the sandy clays, sands, and marl beds of the Yorktown and St. Mary's formations of the Chesapeake group. The marl beds weather light- or bright-colored, but are dark greenish or bluish below water level. The total thickness of the Yorktown formation may be 100 feet. The thickness of the other Chesapeake formations under cover, the St. Mary's, Choptank, and Calvert, is not determinable from the well records available, but the base of the Chesapeake lies about 200 feet below sea level at the western corner of the county, and 300 feet deeper on the shore of Mobjack Bay. Below the Chesapeake lies 150 to 200 feet of Pamunkey greensands, the more glauconitic and porous making the "black sand" of well drillers, while below these are the Upper Cretaceous formations.

UNDERGROUND WATERS.

Distribution and quality.—Both the surficial deposits and the deep sands, except at the east end of the county, contain abundant supplies of

^aThe writer believes that the terrace that occupies the greater part of the area mentioned is to be correlated with the Pamlico terrace of North Carolina.

water. The quality varies greatly; probably no county in Tidewater Virginia can show more variety. On high ground the shallow water is soft and low in iron, except in Chesapeake marl beds. Near Mobjack Bay and at some points along York River the shallow water is of indifferent quality, very hard, high in iron or brackish; at some places it is excellent. The artesian waters show as great variation. At the west end of the county they are soft, clear, and fresh; at the east end they are barely potable, containing salt, sulphate and bicarbonate of soda, and at some wells iron. They are as a rule sulphur-bearing.

Artesian waters under moderate cover, 50 to 100 feet, are found in the eastern end of the county. They have low heads, 2 to 5 feet above mean high tide, and lie in irregular and discontinuous sand and shell beds in the Yorktown formation. The waters as a rule are clear and bright, but more or less limy, and in places very hard and iron-bearing. The deeper sands of the Chesapeake group give higher heads, up to 35 feet, and at some places larger flows. Very soft waters, resembling those of the basal Chesapeake beds, are found in the Pamunkey under the western part of the county, but to the east the Pamunkey sands, like the Chesapeake, as suggested by Darton,^a probably become too fine to transmit water readily. The flows decrease in volume and cease, no flow being known from the Pamunkey east of Gloucester Point. Little is known of the Upper Cretaceous formations, but in the eastern portion of the county deep wells get waters presumably from these formations, that vary in character from the soft, alkaline, slightly sulphur-bearing flow at Gloucester Point to the highly mineralized, saline, ferruginous waters found near Severn River. The Potomac beds have not been tapped within the county west of Selden. They undoubtedly contain potable water in abundance as far east as Claybank.

Springs.—Springs are abundant. Most of them flow from Columbia sands; some from Chesapeake marl beds. Yields are generally small, averaging at such springs as are in any way improved, 5 to 10 gallons per minute; flows as large as 20 gallons per minute are rare. A considerable number are still used for household supply. No spring yields water for shipment in commercial quantities, and none is a health or pleasure resort. A few that have attracted notice by reason of size, location, or quality of water are owned by Dr. C. H. Bradford, near Dutton; F. E. Du Val, near Cash, a large marl spring; Thos. Dixon, Jr., 2 miles west of Dixondale, a bold flow of soft water known as the Cow Spring; C. J. Roane, near Woods

^aDarton, N. H., Artesian water prospects of the Atlantic Coastal Plain, Bull. U. S. Geol. Survey, No. 138.

Cross Roads, irony water; W. R. Stubbs, near Pinetta, hard, iron-bearing water; and G. P. Brown, near Wan.

At Gloucester Point a spring of soft water rises through surface sand from shell-rock in the Yorktown formation. The water is much used by fishermen for boat supply, as it is said to keep well. The flow is about $1\frac{1}{2}$ gallons per minute.

Wells.—Dug wells are practically the sole source of supply on ground over 40 feet above tide level. On lower ground are also dug and driven wells, the latter being particularly numerous toward the east end of the county.

LOCAL SUPPLIES.

At Gloucester are some 15 dug wells from 25 to 40 feet, most of which are lined with brick. There are no springs close to the Courthouse, which is on a ridge, but there are plenty with perennial flow along neighboring creeks. Owing to good drainage, the thick cover of loam, and the depth to water table, dug wells at Gloucester are not likely to be polluted if ordinary precautions are taken to prevent the ingress of surface water.

Near Achilles a number of deep driven wells that do not flow yield water of varying quality. One owned by B. A. Rowe gives water that is reported to work well in a saw-mill boiler. The water may come from beds of Chesapeake age.

The wells along York River from Puropotank Creek to Gloucester Point tap the Chesapeake, Pamunkey, and Upper Cretaceous sands. In general the wells flow soft, alkaline water suitable for all household purposes. The height to which water rises varies; the Chesapeake sands give heads of from 10 to 30 feet, but the Pamunkey gives reported heads of 35 feet at Cappa-hosic and of 25 feet at Timberneck Creek. The flow from the Upper Cretaceous sand, at Gloucester Point, has a head of but 10 feet.

A well 3 miles southwest of Signpine, on a tidal inlet, found salt water at 13 feet, brackish water at 33 feet, and good artesian water at 196 feet, as shown by the following log:

Record of well of R. C. Coleman, 3 miles southwest of Signpine.

(Authority, R. C. Coleman, owner.)

Material	Thickness (Feet)	Depth (Feet)
Yellow sand, salt water at 13 feet.....	13	13
Lighter colored sand, white at base; brackish water at 33 feet	20	33
Blue marl or "marsh mud".....	155	188
Quicksand	$9\frac{1}{2}$	$208\frac{1}{2}$
Hard shell-rock	$\frac{1}{2}$	210
Sand; main flow	1	211
Elevation of surface $3\frac{1}{2}$ feet.		

At Allmondsville several wells have been sunk for oyster houses and boiler supply. The reported depths are about 300 feet, the flow coming from Chesapeake sands. The alkaline water has a slight sulphur odor; it neither pits nor scales a boiler, but has a tendency to foam. A field analysis of the water from one well is given in table 8.

On Jones Creek, B. B. Weaver has a 336-foot well that flows 5 gallons at 5 feet above mean high tide. The water comes from medium fine quartz sand containing much dark green glauconite. The owner dammed a small run and put in a water wheel which he belted to a "bulldozer" pump that forces the water to a tank on a tower near the house; the house is 25 feet above the spring, and the total lift to the tank about 50 feet. Table 8 contains a field assay of a sample of the water.

The well at Cappahosic, 415 feet deep, found no flow in the Chesapeake sands, and the Pamunkey flow is of moderate volume. The owner has harnessed the well to a small ram, a flow of 3 gallons per minute, with a drop to the ram of 6 feet, being sufficient to lift all water needed for domestic use to a tank in the house 40 feet above the river. The overflow from the ram is piped to neighbors' houses, one being 300 yards distant.

The decrease of yield in the Chesapeake and Pamunkey sands near the mouth of York River is shown by a well sunk for James Brown by a driller familiar with local conditions. This well, on Carter Creek, about half a mile from the mouth, found water from 60 to 80 feet in coarse gravel, and no more till a very weak flow at 535 feet; sinking to 610 feet brought no increase in flow and the well was abandoned.

Near Timberneck Creek are artesian wells which get water from the shell beds in the Yorktown formation. One of these, 65 feet deep, at the residence of Charles Catlett, is used for household supply; two other wells sunk to the Pamunkey gave flows of sulphur-bearing water. The flow from the shallow well has a head of 4 feet and shows large tidal fluctuations. The water is clear but hard.

On the beach at Gloucester Point is a well 690 feet deep which gets water from the Matawan; no flows were found, according to the driller, in the Pamunkey or Chesapeake beds, and the Matawan flow is small (2 gallons), and of low head, 10 feet. The well was sunk for public use. The water has a slight sulphur odor, is alkaline, and contains more salt, sulphate of soda, and lime than the wells up the river. In a boiler it foamed badly. A field analysis is given in table 10.

The following record is reported from one of the flowing wells on Pianketank River. The water is probably from the base of the Chesapeake group.

Record of well of R. J. Bristow, 3 miles east of New Upton, on Pianketank River.

Material	Thickness (Feet)	Depth (Feet)
Sand, water at 8 feet.....	15	15
Clay	15	30
Sand	4	34
Blue sand marl; water at 42 to 46 feet.....	201	235
Sand, very small flow of water.....	2	237
Marl	148	385
Soft rock; flow of water, about $\frac{1}{4}$ gal. per minute, at 415 feet	30	415

Near Severn River are several deep wells notable for their highly mineralized waters. All the flows contain considerable salt in addition to sodium carbonate or bicarbonate, and some of the flows are decidedly iron-bearing. The yields vary decidedly, but as a rule are scanty.

At Eagle Point, the country seat of the late Joseph Bryan, several attempts were made to get a sufficient flow of potable water. The most important attempt was a 6-inch well 1,004 feet deep. It penetrated several water-bearing beds but found no water that would overflow, though the elevation of the surface is but 5 feet above tide. Another well, 900 feet deep, yields a scanty flow of clear, saline, alkaline water. (See table 11 for field assay.) A well 100 feet deep gets a flow of decidedly hard water from a shell bed in the Yorktown formation. Cistern water is used for most purposes. Nearby at the residence of A. W. Withers is a 6-inch well 605 feet deep, that taps Upper Cretaceous beds. It flowed, at an elevation of 6 feet above tide, 69 gallons per minute of salty, ferruginous, bicarbonated water that readily corrodes steel pipe. The water is too salty to be palatable. (See table 10.)

At Severn a well 610 feet deep found water at the base of the Pamunkey. The owner gave the following record from memory:

*Record of 610-foot well of J. N. Shackelford, near Severn,
Gloucester County.*

Material	Thickness (Feet)	Depth (Feet)
Clay	1	1
White sand	6	7
Yellow and reddish sand; water.....	1	8
Blue shell marl, small shells.....	10	18
Dark gray sand, water-bearing; "water contained lime but washed well"	6	24
Dark marl and sand mixed.....	46	70
Light bluish marl containing a few shells, and mud.....	355	425
Fine black sand "almost as dark as gunpowder" with one white grain in 50 black; water-bearing but water did not rise to surface	15	440
Soft dark or greenish mud, very few or no shells.....	135	575
Black sand in hard layers, water-bearing, flow 1 gallon in 5 minutes at 5 feet elevation above tide.....	55	610
Below the rock was clean gravel "like fine hail" pebbles size of wheat grains, clear or occasionally bluish; this gravel contained water but the gravel and sand choked the pipe and it was pulled back to 575 feet		

The water is clear, but highly mineralized, containing considerable salt. It has been drunk as a medicinal water. (See table 10.)

Some particulars of dug wells, reported by postmasters, at various points in the county are shown below in tabular form:

Details of dug wells in Gloucester County.

* Location	Depth (Feet)	Water bed	Quality of water
Belroi	10-20	Sand	Hard and soft
Cash	30-45	Sand and marl	Hard
Dutton	18-50	Sand	Soft
James Store	25-50	Sand	Soft
New Upton	35-40	Sand and marl	Soft and hard
Ordinary	10-35	Sand	Hard and soft
Pinetta	25-40	.....	.....
Roanes	20-30	Sand and marl	Hard
Signpine	40	Sand and marl	.....
Woods Cross Roads	30-50	Sand and marl	Soft and hard
Whitmarsh	18-60	Sand	Soft
Wicomico	10-40	Sand and gravel	.....

Conclusions.—Artesian water can be had under the whole of Gloucester County, but the wells already dug demonstrate that liberal flows of good quality can not be expected east of Gloucester Point. Excellent water can be had in the western part of the county under heads of 30 to 35 feet above

tide. At Gloucester Courthouse soft alkaline water can be had by a well less than 500 feet deep, but a deep well pump must be used as the water will probably not rise to within 40 feet of the surface.

GREENESVILLE COUNTY.

General description.—Greensville County includes the extreme southwest corner of the Virginia Coastal Plain, south of Meherrin River, and its southern boundary is the North Carolina-Virginia state line. The Coastal Plain portion of the county lies east of the Atlantic Coast Line Railway, and has an area of about 70 square miles.

The surface shows considerable diversity of relief but much of it is low, and is included within the valleys of Meherrin River, Fontaines Creek, and tributary swamps. The general slope is east. Along Meherrin River the lower Columbia terraces are extensive. The maximum elevations of the Coastal Plain area in this county have not been determined, but the Sunderland terrace is a less important feature of the topography than in counties to the north. Elevations above sea level range from 200 feet, west of Jarratt, to 20 feet along Meherrin River.

Geology.—Granite outcrops in the bed of Meherrin River near Emporia, and lies less than 50 feet below the surface in the town. Near the river the granite is overlain by Columbia gravels, sands, and loams, which also mantle the surface in the vicinity of the town and along the railroad to the south.

Potomac sands overlie the granite a short distance east of Emporia, but are not exposed along Meherrin River nor anywhere within the county. There is nothing to indicate the presence of Upper Cretaceous or of Pamunkey (Eocene) beds. Chesapeake marls are exposed in places by pits from which the marl was dug.

UNDERGROUND WATERS.

Distribution and quality.—The Columbia and the underlying Chesapeake or Potomac sands carry waters that show considerable variation in quality. Sufficient water for household needs can be had anywhere in the Coastal Plain portion of the county at small cost. For larger supplies groups of driven or bored wells have been put down in the Columbia sands, and at least one well has been drilled deep into granite.

LOCAL SUPPLIES.

At Emporia water for boiler supply has been obtained from dug, bored or driven wells. The Emporia Manufacturing Co., in 1905, had 6 bored

wells, 24 feet apart, with 4½-inch casing, and a 2-inch suction pipe having a slotted brass strainer 2 feet long inside the casing; the yield was about 60 gallons per minute of hard water. Soft water was found at 22 feet. The company had also a series of 20 bored wells 16 feet apart, 2 inches in diameter, with 18-inch screens, and only about 22 feet deep. The water normally stood within about 10 feet of surface and the combined yield to pump was 70 gallons per minute. Granite is found at 32 feet.

The town of Emporia has a 600-foot drilled well, described on page 93; it furnished unsatisfactory water from crevices at several depths.

HANOVER COUNTY.

General description.—Hanover County, formed in 1720 from New Kent County, lies between Chickahominy and Pamunkey rivers, but only that part east of the Richmond, Fredericksburg & Potomac Railroad is within the Coastal Plain province. This part, probably 100 square miles in extent, contains several important settlements, the largest being Ashland.

The topography has the varied aspect common to other counties along the "fall line." The Lafayette and older Columbia terraces have been deeply trenched by tributaries of Chickahominy and Pamunkey rivers; maximum elevations are 200 to 225 feet near Ashland, Merryoaks, and Ashcake, while the swamp along Chickahominy River is 50 to 80 feet, and the flood plain or first bottom along Pamunkey River, is 10 to 30 feet above sea level. The Sunderland plain east of Ashland may be 160 to 180 feet high. The Wicomico plain lies along Pamunkey River from near Hanover to Doswell. At the latter place it forms the "second bottom" at an elevation of 60 to 80 feet above tide. A lower plain is well developed near New Castle bridge, where its surface is 25 to 40 feet above sea level. The Wicomico is not well shown in the Chickahominy valley.

Geology.—Granite underlies the Columbia deposits south of Ashland, and the Triassic sandstones outcrop north of Ashland, near North Anna River. Above this basement to the east are Potomac, Pamunkey, and Chesapeake deposits. The Potomac at Belamar is represented by a few feet of dark bluish shale, and on the North Anna near Doswell by arkosic sands and sandstones of the Patuxent formation. The exposures of Eocene deposits along Pamunkey River from Wyckham to Piping Tree Ferry were visited by Conrad and by Rogers over 70 years ago, and have been

examined by many geologists since. The beds consist of dark green sands containing fossil shells which in places form shell-rock. Most of the material exposed is part of the Aquia formation. No Pamunkey (Eocene) beds are exposed in the Chickahominy valley. The Chesapeake (Miocene) beds, chiefly of the Calvert formation, overlap the Pamunkey. They comprise dark greenish sandy clays, which in places contain many fossil shells and in places are full of diatoms. The thickness of the Chesapeake beds varies from a feather edge to possibly 100 feet on the east side of the county.

The Lafayette and Sunderland formations overlap the granite and the Cretaceous, Eocene or Miocene beds to the west, the Lafayette extending an unknown distance westward. The Sunderland contains numerous large boulders of crystalline rocks, evidently ice-borne, and near Wyckham its scarp is as thickly strewn with boulders as a New England hill pasture. On the Wicomico plain along Pamunkey River these sub-angular boulders of gneiss and schist are dug out in tilling fields and used for well-casing, foundation-stone, flagging, etc.

UNDERGROUND WATERS.

Distribution and character.—Water-bearing beds occur in the Potomac, Pamunkey, Chesapeake, and Columbia deposits. The deeper Potomac and Pamunkey waters, as indicated by wells in King William County, are probably of good quality. The water from the Columbia sands is as a rule soft.

Springs.—Springs of the usual Coastal Plain type are numerous, but comparatively few are used for household supply and from none is water sold regularly. The quality of the spring waters varies from hard or iron-bearing to very pure and soft.

One spring of note is near the residence of T. A. Taliaferro about $11\frac{1}{2}$ miles southeast of Pole Green. This spring rises as a bold flow from a bed of white sand (Sunderland) near a little run tributary to Beaver Dam Creek. The spring is said to rise from a depth of at least 20 feet, as a pole can be forced down into the sand to that depth. The flow, about 15 gallons per minute, is clear, soft, and light. The owner furnished an analysis that has been recomputed to express results in the form used by the Federal Survey.

*Analysis of water from spring of T. A. Taliaferro, southeast of Pole Green,
Hanover County.*

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total mineral solids	19.
Silica (SiO ₂)	6.2
Iron (Fe)	0.08
Aluminum (Al)	0.11
Manganese (Mn)	0.02
Calcium (Ca)	0.7
Magnesium (Mg)	0.3
Sodium (Na)	2.2
Potassium (K)	0.8
Lithium (Li)	0.01
Arsenic (As)	trace
Bicarbonate radicle (HCO ₃)	2.7
Sulphate radicle (SO ₄)	2.3
Phosphate radicle (PO ₄)	0.03
Chlorine (Cl)	3.1
Iodine (I)	trace
Free carbon dioxide gas 64 c. c. per liter.	

No improvements had been made at this spring when it was inspected, nor was the water being sold.

Other springs of more or less note in the Coastal Plain section of Hanover County are those of H. Carter Ridd, of Beaver Dam; of M. C. and C. H. Tate, at Ruel, which give iron-bearing water; and a small spring of E. G. Gwathmey, near Taylorsville, said to yield sulphur water.

LOCAL SUPPLIES.

Dug wells at Hanover average 20 to 30 feet deep, though one was dug 60 feet. The water from most of the wells is called "medium soft." The deeper wells go through the Columbia gravels and sands into the Chesapeake beds, and if they strike shell marl the water becomes hard. The 60-foot well found a little hard water at 20 feet on top of a dark, greenish sandy clay of the Chesapeake group, but none for 40 feet below.

At Ashland most of the water used is obtained from dug wells; enough for a family of ordinary size can be obtained by digging 18 or 20 feet. Because of the level surface of the ground and the shallow depth of the water table there is danger of pollution; hence some people use only cistern water for drinking. At Randolph-Macon College cisterns of large size, kept securely locked, are filled during late fall, winter and early spring; the supply being accumulated after leaves have fallen and migratory birds have left the region.

Where there is no danger of pollution from nearby cesspools or wells with unsanitary surroundings, good water from dug wells is had by digging to below water level, dumping in several feet of clear, coarse gravel, and using tile curbing with tightly cemented joints, the top length projecting a foot or so above surface.

Several attempts to get water by drilling have been made at Ashland. One well at Randolph-Macon College, sunk about 100 feet, furnished satisfactory supplies for about ten years, and then was abandoned because an influx of sand choked the pump. A deep well intended to furnish a supply for the college and the town is on the grounds of the Henry Clay Inn. This well, 365 feet deep, went through the Lafayette and obtained its supply from the sandstones of the Newark. The following record is that furnished by the driller:

Record of deep well of Ashland Water and Light Co., at Henry Clay Inn, Ashland.

(Authority, Sydnor Pump and Well Co., drillers.)

Material	Thickness (Feet)	Depth (Feet)
Earth	64	64
Rock	77	131
Sandstone	26	307
Soft brown shale	58	365
Slate	—	365

The following record of a well near Ashland is from Darton's bulletin.^a

Record of well near Ashland.

Material	Thickness (Feet)	Depth (Feet)
Clay and soil	20	20
Gravel and sand	22	42
Blue clay with beds of fine sand	37	79
Stratum of sandstone	6	85
Disintegrated stone, with water in its upper portion	35	120
Granite	20	140

In 1910, a public supply system, taking water from two deep wells, was installed.

On the lower terrace near Pamunkey River many shallow wells 10 to 15 feet deep get water enough for family use, but are frequently filled by

^aDarton, N. H., Op. cit. p. 179.

surface water during rains, and are not considered wholly safe. A deep well sunk for locomotive supply by the Richmond, Fredericksburg & Potomac Railroad, near Doswell, elevation 55 feet, obtained, from the Newark rocks at a depth of about 300 feet, hard water, which rose to within 3 feet of the surface. The supply was either insufficient or unsatisfactory, for the well was abandoned by the railroad company and later covered in widening the grade.

About Wyckham, wells on the Sunderland plain get soft water at depths of 30 feet or less. Near Wyckham station on the scarp above the Wicomico plain an attempt to get water by digging into the Chesapeake marls and clays was unsuccessful. The following section was furnished by W. W. Dyson, superintendent of Hickory Hill farm.

Record of 75-foot well at Hickory Hill, Wyckham.
(Authority, W. W. Dyson.)

Material	Thickness (Feet)	Depth (Feet)
Loam and pebbles	5	5
Red clay	4	9
White "fuller's earth"	10	19
White and purplish "fuller's earth" with iron stains.....	10	29
Dark bluish black "fuller's earth".....	8	37
Blue gravel and sand, pebbles large as hens' eggs	3	40
Blue sand	2	42
Shell marl, very hard, full of scallop and clam shells and sharks teeth	11	53
White sand, water-bearing	1	54

The water rose to the top of the marl. It tasted strongly of iron, and was so hard that it could not be used for washing, consequently the well was filled.

Shallow well conditions at a number of points in the Coastal Plain section of the county are given in the following table:

Details of dug wells in Coastal Plain portion of Hanover County.

Location	Depth (Feet)	Water bed	Quality of water
Belamar	12-100	Sand and rock	Soft and hard
Doswell	15-35	Sand	Soft
Beaverdam	15-30	Sand	Soft
Pole Green	30	Sand	Soft
Ruel	30	Sand	Soft

Conclusions.—There is little chance in Hanover County for artesian water that will rise above tide level, but in the eastern part of the county water of good quality and softer than that obtained by dug wells can be had by drilling. The Newark rocks are uncertain water-bearers, and though water can probably be had from them the quality and yield can not be predicted; both may be good, as at Ashland, or poor, as at Doswell.

HENRICO COUNTY.

General description.—Henrico County, formed in 1643 as one of the original shires of Virginia, lies between James and Chickahominy rivers, part of the county being in the Coastal Plain and part in the Piedmont Province. Richmond, the capital of Virginia, a prosperous manufacturing city, had a population of 127,628 in 1910. The area of the Coastal Plain portion is about 350 square miles. Outside the city limits are a number of suburbs, chiefly residential, such as Barton Heights, Brookland, Ginter Park, and Highland Springs. The population of the county, exclusive of Richmond, was 23,437 in 1910.

Away from the railroads and the immediate vicinity of Richmond the county contains few villages of importance. Along the James River are several famous estates, and one of the largest single farms in the State, measured by land under cultivation, is about 15 miles below Richmond.

As Henrico County lies partly in the Coastal Plain and partly in the Piedmont Plateau the topography is characterized by the gently undulating remnants of the high Lafayette or Sunderland plains on the inter-stream areas, with precipitous scarps along the gorge of James River, the gorge at Richmond being nearly 250 feet deep. The Lafayette plain has an elevation of 200 to 225 feet. The lower terraces are not well developed near Richmond, but can be traced along the James River valley below.

The Coastal Plain area contains few creeks or runs more than a few miles long. Those emptying into the James such as Shockoe, Gillies, and Almond creeks, have cut sharp valleys which are marked features of the topography. Along Chickahominy River is a cypress swamp, lying 50 to over 100 feet above tide level and in places over a mile wide.

Geology.—The gray granite-gneiss over which James River flows at Richmond is exposed at higher elevations in railroad cuts west of the "fall-line," as at Glen Allen. It dips eastward from the "fall-line" about 40 feet to the mile, and above it lie Potomac, Pamunkey, and Chesapeake beds, all of which outcrop in the city limits of Richmond. The Patuxent formation, with arkosic, incoherent or indurated sands full of pebbles,

cobbles, and clay balls, may be seen along Gillies and Almond creeks. The Pamunkey greensands and the Chesapeake diatomaceous clays are exposed at the famous outcrop on the west bank of Shockoe Creek, just below the plant of the American Locomotive Works, where, in a bluff about 40 feet high, dark argillaceous Pamunkey greensands of the Nanjemoy formation grade into dark diatomaceous clayey Chesapeake sands of the Calvert formation. Higher up the run are many outcrops of the Calvert formation full of shells. North of the city, near the State Fair grounds, dark fossiliferous Chesapeake marls and clays rest directly on the granite. Along James River, south of Richmond, notably at Dutch Gap, many outcrops of Potomac sands and standstone can be seen. In Chickahominy valley the dark, sandy clays of the Chesapeake beds are exposed along the creeks and runs. From feather edges on the west, the Potomac, Pamunkey, and Chesapeake beds thicken rapidly down the dip, and at the eastern edge of the county the Potomac may be 300 feet thick, and the Pamunkey and Chesapeake, each 100 feet.

UNDERGROUND WATERS.

Distribution and character.—The occurrence of water in the granite has been described on pages 83-97. The Potomac beds are prevailingly coarse-textured, and contain much water that is available to wells. The Chesapeake sandy clays are dense and the Calvert formation is probably a poor water-bearer within the county limits. The loams and sands of the Columbia contain large supplies of ground water, the depth of the water table below surface depending on the topography. The shallow waters are for the most part soft. Little is known of the quality of the water to be had by deep wells sunk to the Potomac beds.

Springs.—Springs abound. Most are small seeps from beds of sand but a few are of considerable size. One of the largest in the county, known as the Tucker or Bonanza spring, is near Highland Springs on land owned by E. S. Reed. It is situated in a hollow near a small run that flows into Chickahominy River. The water rises from sands and gravel, evidently slope wash, and the geologic relations of the spring are not evident. The water probably comes from near the contact between the Chesapeake and the overlying Columbia sands. The flow, about 28 gallons per minute, is said not to vary during the year. The water is soft, clear, tasteless, and odorless, has been used for drinking purposes by several families at Highland Springs, and has been shipped to Richmond.

Situated a few miles west of Highland Springs, in the Sunderland scarp facing James River, is Como Lithia Spring, the water of which is sold for medicinal and table use. The spring issues from sand beds at the base of the Sunderland formation. The water is clear and sparkling, tasteless and odorless, and contains free carbon dioxide which makes it agreeably light. The following analysis, recalculated to express results in standard form, was furnished by the proprietor of the spring, I. M. Hawks.

Analysis of Como Lithia water.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	34.
Organic matter	slight trace
Silica (SiO ₂)	5.4
Iron (Fe)	0.1
Aluminum (Al)	0.53
Calcium (Ca)	0.86
Magnesium (Mg)	1.1
Sodium (Na)	4.7
Potassium (K)	2.1
Lithium (Li)	0.07
Iodine (I)	0.39
Bromine (Br)	trace
Arsenic (As)	trace
Bicarbonate radicle (HCO ₃)	7.9
Sulphate radicle (SO ₄)	0.41
Chlorine (Cl)	10.
Free carbon dioxide gas, 31 c. c. per liter.	

The spring is in a park with no buildings near, and pollution by contaminated surface waters is improbable. The only improvements at the spring, when inspected, were a bricked pool from which the water was pumped, and a rustic spring house.

Other springs of more or less note in Henrico County are those of E. G. Hopkins, at Glen Allen; of William Dean, on the edge of a slope from the Sunderland plain, 2 miles northeast from Fair Oaks; of A. A. Carlough, half a mile south of Elko; of J. W. Francis, 3½ miles south of Chickahominy; of J. T. Brown, on the Sims place, 3 miles south of Laurel station; and a spring on the Crenshaw tract, 1½ miles east of Laurel. The spring that supplies Barton Heights is mentioned on page 190.

Wells.—While the larger proportion of the dug wells in the rural parts of Henrico County are curbed with wood, there are many, especially near Richmond, that are bricked. Most of the bricked wells are covered and have pumps. There are some driven wells, but outside of Richmond there are few drilled wells.

LOCAL SUPPLIES.

The city of Richmond owns waterworks which distribute James River water. In or near Richmond a number of deep wells have been sunk by hotels and industrial concerns. These wells get water from fissures and joints in the granite, and are of much interest because of the wide variation in yield and quality of water. They are discussed in detail under the heading "Wells in crystalline rocks," on page 83.

A dug well 12 feet in diameter and 112 feet deep at Benjamin Davis' brickyard in the north part of the city is situated just on the edge of the Sunderland plain above Bacon Quarter Branch. It went through Columbia cobble beds and loams and the Chesapeake sandy clays to decomposed granite, but struck nothing that could be identified as Potomac material, and yields little water.

In the Brookland district, which includes residential and manufacturing sections, northwest and north of the city, and had a total population of 10,068 in 1910, water is obtained chiefly from dug wells 10 to 40 feet deep, though there are many drilled wells and some cisterns.

Within a mile of Highland Springs there are over 100 dug wells, which obtain supplies of soft water from sand beds, and range in depth from 20 to 27 feet with an average of about 32 feet.

In Glen Allen dug wells are 20 to 35 feet deep, and most of them strike granite at about 20 feet. The Old Dominion Excelsior Co. has two wells 8 feet square and 22 feet deep that go to the granite, and are connected by a cresscut at the bottom.

Barton Heights, a suburb of Richmond, with a population of 1,388 in 1910, has a public supply from the Mitchell Spring and an adjacent dug well 15 feet in diameter and 44 feet deep, in the scarp back of the spring. The yield reported is about 100 gallons per minute. Some characteristics of the water, which is considered good, are shown by the following sanitary analysis:

Sanitary analysis of water from Mitchell Spring.

(E. C. Levy, analyst.)

	Parts per 1,000,000
Total solids	106.
Loss on ignition	42.
Alkalinity	0.0
Chlorine (Cl)	16.5
Nitrates (NO ₃)	0.445
Nitrites (NO ₂)	0.0
Iron (Fe)	0.03
Total hardness	32.5

To supplement the supply from this well and spring, the town, in 1909, had a deep well sunk on the east side of the valley of Bacon Quarter Branch. This well, 759 feet deep, yields to a pump 40 gallons a minute of excellent water.

The drilled wells at Barton Heights go through Columbia and Chesapeake beds, getting water from crevices in the granite-gneiss. Most of the drilled wells are from 50 to 150 feet deep, though a few are much deeper.

At Fort Lee, dug wells 15 to 25 feet deep go through red clay into blue marl and then into water-bearing sand. The cost of digging such wells has been \$6 or \$7. Some of the wells seen were liable to pollution because of insufficient protection at the top.

At Chestnut Hill and Highland Park nearly all householders have dug wells 20 to 40 feet deep, averaging about 30 feet at Highland Park. The water generally is soft.

At Ginter Park most houses are supplied from the deep well described on page 92. Dug wells are 20 to 35 feet deep. One at the Jefferson Laundry yielded water that was too hard for laundry use. Analyses of water from these wells are given in tables 4 and 7.

No account of deep wells in Henrico County would be complete without mention of the boring at Curle's Neck, the 7,000-acre farm of C. H. Senff. This well near James River where the Talbot terrace plain has a maximum elevation of about 30 feet, went through Columbia, Chesapeake, Pamunkey, and Potomac deposits, striking granite at 310 feet. According to Mr. Bedell, superintendent at Curle's Neck, a little sulphur-bearing water was found at 125 and 250 feet, and drilling was continued to 725 feet. In the granite water was struck at various depths, better in quality but less in volume than that above, and at 710 feet the well was temporarily abandoned. After remaining idle for a year, it was tested and the most that could be had was about 10 gallons per minute. As a last resort six or seven charges of dynamite, some 45 pounds in all, were exploded at various depths in the granite, with complete success. Mr. Bedell said that pumping at the rate of 100 gallons per minute continuously for three weeks lowered the water level but a few inches. The water, which is piped to several houses for domestic use and is drunk by 75 to 100 persons, is soft, clear and colorless, without taste or odor.

The depths of dug or driven wells, character of water bed, and quality of water at a number of places in the county are summarized below:

Details of dug wells in Henrico County.

Location	Depth of well (Feet)	Water bed	Quality of Water
Elko	15-25	Sand and gravel	Soft and hard
Fair Oaks	18-22	Sand	Soft
Glendale	15-60	.....	Soft
Highland Park	20-25	Loam and sand	Soft
Highland Springs	20-40	Sand and gravel	Soft
School	20-50	Rotten granite	Soft
Seven Pines	About 20	Sand	Soft
Varuna Grove	About 30	Sand	Soft

Conclusions.—As the Lafayette and higher Columbia terraces have a thick covering of clay loam it is probable that dug wells, even when houses stand closely, will be satisfactory from a sanitary standpoint, provided that wells are properly protected, and provided they are not sunk close to cess-pools or privies. Drilled wells properly cased are, however, preferable. Good water can probably be had by wells drilled to the Potomac beds in the eastern part of the county, but the prospects for flows, even at an elevation of less than 10 feet above tide level, are poor.

ISLE OF WIGHT COUNTY.

General description.—Isle of Wight County, formed in 1634 as one of the original shires of Virginia, lies south of James River and east of Blackwater River. Smithfield, with a population of 1,278 in 1910, is the only incorporated town.

The general slope of the surface is southeast. It varies from flat to gently undulating, though the Columbia terrace plains are somewhat sharply cut along the north and east by creeks flowing to James and Nansemond rivers, of which Pagan Creek is the most important. The creeks in the western and southern parts of the county drain to Blackwater River, have open valleys, and flow sluggishly through cypress swamps. The divide between the James River and Blackwater River drainage runs through the center of the county. Along James River and Pagan Creek the descent from the Wicomico plain to tide level is generally abrupt, there being bluffs along the James 50 to 80 feet high. The slope southwestward from the Blackwater-James divide is gentle, Moonlight having an elevation of 85 feet and the Blackwater bottoms opposite Franklin 30 feet.

Noteworthy features of the topography in the northwest corner of the county, commented on by Rogers,^a are the wide, poorly drained tracts known as pocosons.

Geology.—The mantle of Columbia loams and sands hides the older beds except along the river and creek valleys. The Potomac and Pamunkey deposits are deeply buried, and the only outcropping Chesapeake formations are the Yorktown and St. Mary's. The sands, clays, and shell marls of the former in places constitute the whole thickness of the bluffs along James River, and at some localities, for instance near Fort Boykin, are beds crowded with marine shells that here and there form hard rock. The thickness of the Yorktown may be 100 feet; of the St. Mary's about 250 feet. The formations are much alike, being differentiated by fossils. The top of the Pamunkey is from 200 to 400 feet below tide level. Nothing positive is known of the Upper Cretaceous beds nor of the Potomac.

UNDERGROUND WATERS.

Distribution and quality.—The Potomac, Pamunkey, and Chesapeake groups contain artesian water. The coarser sands will yield supplies at any point in the county, and along James River will give flows at elevations below 25 to 35 feet. Nothing is known of the quality of the Potomac and Pamunkey waters, but there is every reason to believe that they are potable. The artesian waters in the Chesapeake beds are soft, alkaline, and adapted to domestic use. The shallow water varies in quality from soft in the Columbia sands to hard in the Chesapeake shell marls.

Springs.—There are many springs along tributaries of James and Blackwater rivers, but few of especial importance. Most springs flow from Columbia sands, and a few from the top beds of the Chesapeake.

Near St. Luke's church, built in 1632 (Benn's Church post-office), is a wayside spring of good flow, about 10 gallons per minute, that has been used by wayfarers for nearly 300 years. Its clear, fresh, but hard water flows from shell marls in the Yorktown formation.

Wells.—Dug wells with wood-lining are most widely used. In some places, particularly in the northern part of the county, curbing of 24-inch tile is being substituted for wood. The shallower wells, as a rule, reach Columbia sands and loams; the deeper wells penetrate Chesapeake sand or marl. There are some driven wells scattered in the county, and there are many drilled wells along James River, Everets Creek, and Blackwater River.

^aRogers, W. B., *Geology of the Virginias*, 1885.

The drilled wells are nearly all of small diameter, $1\frac{1}{2}$ or 2 inches. Depths range from 40 to over 300 feet. Some have but 20 feet or so of casing; others, and especially those drilled recently, are cased to the bottom.

LOCAL SUPPLIES.

Flowing wells along James River.—The town of Smithfield is supplied with water from a creek 3 miles to the west. In the town are a few dug wells which get hard water, and a considerable number of cisterns. A drilled well 300 feet deep found a fine flow of soft alkaline water in the basal Chesapeake (Calvert) beds that are tapped by some wells a few miles farther up the river.

Along James River, above Smithfield, are several flowing wells about 300 feet deep. A part of the flow from one of the wells at a hotel near Day's Point is bottled and sold by the owner as a table and medicinal water. It belongs to the sodic alkaline bicarbonated class, and like waters of this class in the tidewater country, contains little lime in proportion to the total solids in solution. As a table water it is light and pleasant. The mineral content is shown by the following analysis:

Analysis of Day's Point Artesian Lithia water.
(Froehling and Robertson, analysts.)

	Parts per 1,000,000
Total solids	434.
Silica (SiO_2)	12.
Iron (Fe)	0.19
Aluminum (Al)	0.53
Manganese	.008
Calcium (Ca)	2.6
Magnesium (Mg)	1.1
Sodium (Na)	169.
Potassium (K)	6.2
Manganese (Mn)	0.008
Iodine (I)	0.004
Lithium (Li)	0.008
Bromine (Br)	0.36
Arsenic (As)	trace
Carbonate radicle (CO_3)	204.
Sulphate radicle (SO_4)	11.
Phosphate radicle (PO_4)	0.85
Chlorine (Cl)	25.
Carbon dioxide (CO_2) combined	165.
Free carbon dioxide (CO_2) 2.6 cu. in. per liter.	

A well near by, owned by J. P. Tower, is said to penetrate the following succession of beds:

Record of well of J. P. Tower, 3 miles east of Shoal Bay.

Material	Thickness (Feet)	Depth (Feet)
Soil	1½	1½
Yellow sandy clay	10½	12
Yellow shell marl	18	30
Blue shell marl	140	170
Reddish or "liver-colored" mud.....	4	174
Blue marl with sandy beds, rocks at base.....	106	280
Black sand	4	284
Rock	3	287
Blue marl, water	16	303

These wells are on a bluff 30 feet above James River, hence they yield small flows.

The flowing wells near Everets tap local sands high in the St. Mary's formation. The flows are weak, but the water is of good quality—a little harder and less alkaline than that from the deeper Chesapeake (Calvert) beds along James River. The wells were inexpensive, costing only 10 cents per foot for the driller's time, the owner providing the necessary extra labor and the pipe.

Flowing wells along Blackwater River.—On the west side of the county, in the bottom lands along Blackwater River, flowing wells have been drilled from north of Zuni to the south end of the county below Franklin. The wells tap sands lying in the Chesapeake group (St. Mary's formation) about 150 feet below tide level. Most of these wells are of small diameter (2 inches), and are used for household supply or for watering stock. There are several near Zuni. At the plant of the Shaw Lumber Co., at Ivor, elevation 60 feet, a 6-inch well supplies water for a number of houses; because of the elevation the water does not rise to the surface and a pump is used. For details of other wells, see table 5.

Conditions at some of the villages depending chiefly on dug wells are noted in the following summary, compiled from reports of various persons:

Details of dug wells in Isle of Wight County.

Location	Depth of wells (Feet)	Water bed	Quality of water
Benn's Church	12-20	Sand	Soft and hard
Bobs	12-40	Sand and marl	Soft and hard
Carrsville	15-24	Sand and clay	Soft
Chuckatuck	18-20	Marl and blue clay	Hard
McClelland	10-30	Sand and marl	Soft and hard
Moonlight	12-15	Sand	Soft
Raynor	10-100	.....	Fair
Wells Corner	12-16	Sand	Soft
Windsor	12-18	Clay and sand	Soft, irony
Whitely	10-15	Sand	Soft

Conclusions.—While more care than formerly is now being taken in the location and protection of dug wells, there are many that are liable to pollution. Artesian water of satisfactory quality can be had anywhere in the county at a maximum depth of 300 feet below tide, but to drill with the expectation of getting flows at points higher than 35 feet above sea level will probably prove a waste of effort, except near James River, where carefully cased wells may find water that will rise 40 feet above sea level. Potable water can be found at greater depths, and the Potomac group in particular contains vast supplies. There is nothing to indicate that the Potomac water will not be potable at 1,500 feet below surface, though in the northeast corner of the county these very deep waters are liable to be more mineralized than those obtained from the Chesapeake beds.

JAMES CITY COUNTY.

General description.—James City County, one of the original eight shires of the colony of Virginia, lies north of James River and Chickahominy River, and south of York River. Historically, the county is noteworthy for containing Jamestown, the site of the first permanent settlement of English-speaking people on the American continent, and Williamsburg, the first incorporated city in Virginia. At Williamsburg is William and Mary College, the original charter of which antedates that of Harvard College, making it the oldest chartered institution of learning in the United States.

Situated between York and James rivers, the county has characteristic topography of the western shore type; the Sunderland terrace forms the divide but has been dissected by streams flowing to the rivers on either side. The principal streams are Diascond Creek, a tributary of Chickahominy River; Ware and Taskinash creeks, which empty into York River; and Warwick River, a tributary of York River, which separates the county from Warwick County on the northeast. The greatest elevation of the Sunderland plain is in the northern part of the county between Ware and Diascond creeks, where it is about 130 feet high. Along York River there are only small patches of the Wicomico terrace, but along James River, and particularly along Chickahominy River, there are some wide stretches of it having an altitude of from 50 to 80 feet. The lowest plain is better represented along James River than along York River, and is especially conspicuous in the vicinity of Jamestown Island.

Geology.—The Potomac and Pamunkey beds lie below tide level. The top of the Potomac or Upper Cretaceous is 320 feet below tide level at the

west end of the county, and 580 feet at the east end. The top of the Pamunkey is 180 to 380 feet below sea level. Of the Chesapeake formations only the Yorktown and St. Mary's outcrop. Their characteristic dark greenish or bluish sands and sandy clays and included beds of shell marl, weathered to reddish, buff and yellowish tints, are seen at marl pits. The total thickness of the St. Mary's exceeds 200 feet, but is not exposed above tide water within the limits of the county.

UNDERGROUND WATERS.

Distribution and quality.—Ground water, found in the Columbia and Chesapeake formations, is mostly soft, but in places marl beds yield hard, irony water. The water from the Pamunkey and Chesapeake beds has all the characteristics of that from corresponding horizons in adjoining counties. It is beautifully clear and slightly alkaline, but at some places is sulphur-bearing. Though plenty of potable water can undoubtedly be obtained from the Potomac beds little is known of their possibilities.

Springs.—There are a great many springs in the county, but none of commercial importance. They are used to some extent for household supply, but mostly for watering stock. The waters resemble those obtained from shallow wells in being clear and soft when flowing from Columbia sands, and hard or even iron-bearing when issuing from Chesapeake marl beds. Springs of perennial flow are numerous, but flows of more than 10 gallons to the minute are few.

Wells.—Dug wells are the chief source of domestic supply. Some drilled wells have been sunk near Williamsburg and along the river, but the number is not large. The prices for sinking these have varied according to the diameter, etc. A number of 3-inch wells near Jamestown cost about \$1 per foot, complete.

LOCAL SUPPLIES.

Williamsburg, with a population of 2,044, had no public water supply system in 1906; the inhabitants relied chiefly on dug wells, though there were some cisterns in the town. The deeper dug wells get hard and irony water from the Chesapeake marls. As the town was without sewers, and the location and surroundings of some wells made their pollution easy, and as water from these wells may travel through the marls a considerable distance without undergoing purification, the quality of the water from the dug wells in the central part of the town was not above suspicion.

The deep wells at William and Mary College, the Eastern State Hospital for the Insane, the ice plant, and the knitting mill, particulars of which are given in table 5, tap coarse greenish sands full of shell fragments near the base of the Chesapeake. The water rises about 35 feet above mean high tide in James River, and as the surface elevation is 60 to 80 feet, pumping is necessary. At William and Mary College, the knitting mill, and the ice plant, deep well pumps are used; at the Eastern State Hospital an air-lift. Two wells supply the hospital; one is 8 inches in diameter; the other, owned by the Marshall estate, is 6 inches. The supply from the first is about 50 gallons per minute and from the second 100 gallons per minute. Thirty-five horse power is required to drive a duplex air compressor (air cylinders $18\frac{1}{4}$ by $12\frac{1}{4}$ by 12 inches), which furnishes air under a pressure of 75 pounds per square inch to both wells. The water runs to a reservoir, whence it is forced by a steam pump to an elevated tank. Both wells still throw considerable sand containing fragments of Miocene shells up to several inches in diameter, though the wells have been pumped steadily for over 10 years. The water is used by about 1,000 persons. An analysis made by Dr. W. H. Taylor, State chemist, is given in recalculated form in table 8. An increased supply for the asylum, if needed, can be obtained without great difficulty by deepening the present wells, or by sinking new wells 200 feet or so deeper.

The well at William and Mary College has a deep well pump, geared to a 4-horse power gasoline engine. The yield is about 50 gallons of water per minute. The water is forced to a 30,000-gallon tank on a steel tower 75 feet high. About 200 people used this water in 1906.

The general similarity of the water from the Williamsburg wells is shown by the analyses in table 8. Except for a tendency to foam it works well in a boiler, neither forming scale nor corroding. In the open air it corrodes iron, and tanks on steel towers need to be kept tight to prevent damage to the towers.

Of the wells on York River, one of the most notable is that of W. H. Davis, 235 feet deep, on Taskinash Creek, 2 miles north of Croaker. The water has been sold in small amounts for medicinal and table purposes. An analysis, recalculated from one furnished by the owner, is given in table 8.

A flowing well on Chisholm Creek, 8 miles southwest of Lightfoot, owned by the Powhatan Fish and Gun Club, gets water from a mid-Chesapeake bed at 148 feet.

The flows from recent wells near Jamestown Island deserve particular notice because of their volume and head. The wells (see table 8) get

water between 270 and 300 feet below mean high tide in greensands that in places contain pebbles over a half inch in diameter. One of these wells, that of W. H. Ayers, is but 3 inches in diameter yet flows 85 gallons per minute at an elevation of about 15 feet above high tide; the head is 43 feet. This well, at the time it was completed, had perhaps the best flow of any in Tidewater Virginia having the same diameter. The greensand of the water bed contained pebbles of quartz and silicified limestone nearly 1 inch in diameter. Frank Carman, the driller, procured from a nearby well belonging to Chas. Babcock a series of samples, from which and his notes the following log has been compiled:

Record of well of Charles Babcock, 1 mile north of Jamestown.

(Authority, Frank Carman, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil and red clay (no sample).....	6	6
Reddish sand (no sample); water at 15 feet.....	10	16
White sand and small gravel; water at 45 feet.....	39	54
Dark bluish clay (dark greenish, slightly sandy, micaceous clay, with shell fragments).....	45	99
Grayish sand	10	109
Shell marl, hard layer of shell rock, drill drops in going through	30	139
Grayish sand	10	149
Light-colored mud, soft at top, tough at bottom.....	13	162
Very hard gray sand, light stream of water at about 170 feet, would not rise to surface (sample at 173 feet contained glauconite).....	16½	178½
Coarse gray sand	2½	181
Coarse black sand (quartz sand full of dark green to black glauconite; sharks tooth at 193 feet; light stream of water at 190 feet, rose to 10 feet of surface).....	45	226
Blue mud (dark sandy clay, slightly glauconitic).....	25	251
Blue marl, at wells nearby a stiff red clay which choked pipe	3	254
Black sand (coarse quartz sand full of dark glauconite) runs badly and clogs drill pipe, water at 260 feet.....	26	280
Shell bed in sand	5	285
Sand and shells	4	289
Sand rock	21	310
Sand, with coarse gravel; water-bearing.....	10	320

Other fine artesian wells in the immediate vicinity are owned by J. H. Franklin and S. W. Grimes. On Jamestown Island, in the rear of the ruins of the old church, a well 6 inches in diameter was sunk in 1905 for the Society for the Preservation of Virginia Antiquities, that owns the ground on which stands the ruins of the church and of Lord Ware's residence. The well flows about 40 gallons per minute at an elevation of 8 feet above high tide. The greensand water bed contains large pebbles.

The water from all the wells near Jamestown Island resembles that from the wells at Williamsburg. A field assay of a sample from the well of W. F. Ayers is given in table 8.

The villages in the county, except Bacon, Jamestown, and Iola, stand on high ground near the line of Chesapeake & Ohio Railway, and get water from dug wells. In places, as near Iola, a spring yields hard water, while a well nearby gives soft water. Such an occurrence of soft water below hard is to be explained by inequalities in the contact between the Chesapeake and the overlying beds. The spring flows from a marl bed in the Chesapeake, while the well on the terrace below does not reach the Chesapeake. The well showed the following section:

Record of well at Iola.

Material	Thickness (Feet)	Depth (Feet)
Yellow loam and clay	20	20
White sand	2½	22½
Yellow sand	2½	25
Sand, pebbles, and cobbles; water.....	5	30

The depths of wells, character of water bed, and quality of water at several post villages are shown in the following table:

Details of some dug wells in James City County.

Location	Depth (Feet)	Water bed	Quality of water
Bacon	10-15	Sand	Soft and hard
Diascond	15-62	Sand and clay	
Ewell	30-40	Sand and marl	Soft and hard
Iola	10-30	Sand and marl	Soft and hard
Toano	20-40	Sand and gravel	Soft

Conclusions.—Good artesian water can be had nearly everywhere in James City County, but flows can not be expected at elevations greater than 30 feet above tide level. The entire practicability of supplying Williamsburg with soft water free from bacteria is shown by the deep wells already drilled. Larger flows than those now obtained can be had by going to sands 200 feet deeper.

KING AND QUEEN COUNTY.

General description.—King and Queen County, formed from New Kent in 1691, lies north of York and Mattaponi rivers. Walkerton, the largest village, has a population of about 250.

Most of the southern part of the county lies between Mattaponi and Pianketank rivers, but much the larger portion of this part and all the northern part drains to the Mattaponi River, Forge Mill Swamp, and Chesetank Creek being the most important tributaries of the Mattaponi rising within the county. Pianketank River, which rises in Dragon Swamp, is peculiar in having no important tributaries throughout its course. The general relief of the county is like that of much of Tidewater Virginia. The divide between Pianketank and Mattaponi rivers is formed by the undulating Sunderland plain, which is deeply trenched by tributaries of the latter stream. Lower terraces are found along the rivers. The maximum elevations of the Sunderland range between 180 feet at the northwest end of the county, and 100 feet near the southeast end.

Geology.—The greensands of the Nanjemoy formation (Pamunkey) and the sands of the Calvert and Choptank formations (Chesapeake) are exposed along Mattaponi River. The Pamunkey greensands and shells show above low tide level from Beverly Creek to above Walkerton.

The Potomac beds are deeply buried. Of the surficial formation of the Coastal Plain, the Lafayette does not reach as far east as the western end of the county, but all the Columbian formations are present, their clayey and sandy loams forming much the greater proportion of the soils. These formations, the Sunderland especially, are more pebbly toward the western end of the county.

UNDERGROUND WATERS.

Distribution and quality.—The existence of water-bearing sands in the Chesapeake, Pamunkey, and Potomac formations has been proved by artesian wells along Mattaponi River. Most of the wells, at Walkerton and below, get water from Pamunkey greensands, or possibly sands of Matawan age, though in the lack of fossil evidence it is not possible to say that Upper Cretaceous beds extend as far west as King and Queen Court-house. None of the sands tapped gives flows at over 40 feet above sea level.

All the artesian waters are soft and alkaline from bicarbonate of soda. The iron and lime content are generally low; the proportion of common salt present is remarkably low under the western part of the county, but increases a little toward the east. Most of the flows are not noticeably sulphur-bearing.

The shallow waters vary; most of those in the Sunderland and Wicomico formations are soft. Shallow water in Chesapeake beds is liable to be hard.

Springs.—Springs are numerous, as stream valleys and gullies cut through the Sunderland and later Columbia formations and expose the

less permeable beds of the Chesapeake. Many of these springs are of fair size, but none is of commercial importance.

Wells.—Dug wells ranging in depth from 10 to 40 feet are the principal sources of domestic water supply. Driven wells are comparatively few. Along Mattaponi River is a considerable number of drilled wells, 120 to 300 feet deep.

LOCAL SUPPLIES.

At Walkerton dug wells were for many years the sole source of domestic supply. Now there are only three or four dug wells, which are mostly at barns. They get water at depths of 18 to 25 feet in the terrace above Mattaponi River. Water for drinking and household purposes, also for a pickle house, is obtained from artesian wells of which over 20 have been put down. All but one or two get water from Pamunkey sands which lie 200 feet or more below tide level. The deepest well, that of John A. Mitchell, was bored for coal which was supposed to underlie the village. It went down 372 feet but found no coal and no flow below a free one at about 250 feet. The shallowest well, that at the steamboat wharf, is said to be but 180 feet deep, yet it flows a good stream. One well owned by the Mattaponi Pickle Co. gets its flow from the Potomac at a depth variously stated as 330 and 350 feet, but found several flows above the one developed.

No records of the Walkerton wells were kept, but all the beds went through "rock" and found water in black or gray sand below. One well drilled in 1906 flowed a little sand for a few months after it was completed. This sand which came up through a $\frac{3}{4}$ -inch pipe extending to the bottom of the well, 235 feet, consisted of medium fine quartz grains with black and dark green granules of glauconite.

The later wells at Walkerton have casing to the first rock struck or have pipe to the bottom, but the earlier wells were cased only about 20 feet. Many of these wells undoubtedly leak below the casing, have become clogged by sand, and have had their yields reduced by wells at lower elevations, tapping the same bed. Some wells on the terrace, 30 feet above the river, flow very weakly at high tide and at low tide barely drip, though when first completed they flowed strongly. The original head of the deeper Walkerton wells was probably 35 to 40 feet above mean high water.

All the wells yield alkaline water, which at most wells has a faint sulphur odor. The field assay in table 9 shows the softness, the low chlorine content, and the decided alkalinity, characteristics of the flows. This water can be used in a horizontal boiler, but foams badly in a vertical boiler.

Above Walkerton on Mattaponi River is a fine well, drilled at the bottom of a bluff in front of the residence of A. B. Gwathmey. It is but

190 feet deep, but flowed at an elevation of 8 feet, fully 35 gallons per minute. The head is 35 feet, so that while the water will not rise to the level of the ground on which the house stands, 40 feet above the river, it can easily be raised by a ram. The water bed is described as black and green sand below a rock. Samples showed the rock to be a medium-coarse, indurated sand, containing much dark glauconite and many shell fragments; it might be termed a glauconitic sandstone. At a 275-foot well, owned of John N. Ryland, half a mile from the river, the water rises to 17 feet from surface or about 40 feet above tide, and has to be pumped.

Below Walkerton, near the mouth of Mantapike Creek, a 150-foot well, owned by the Mantapike Canning Co., flows 20 gallons per minute of excellent water from basal Chesapeake beds. The actual cost of sinking was about \$35.

At King and Queen Courthouse a deep well, owned by the county, formerly flowed, but in 1906 was pumped, the water rising about to the surface. It threw much fine sand which contained grains of glauconite.

Along Mattaponi River below the Courthouse and along York River are many flowing wells. At Chain Ferry are two about 168 feet deep. The flow comes from the same Chesapeake beds that supply most of the many wells at West Point, and the waters are of essentially the same quality, soft, alkaline, and slightly sulphuretted. (See field assay in table 8.)

Near the east end of the county a well near Gressitt, belonging to W. F. Anderson, is cased to rock, and after being in use 11 years flowed 8 gallons per minute at 11 feet above tide. It taps the same beds as the wells at Chain Ferry, and the water is of the same general quality.

A number of villages report the data shown in the following table:

Details of dug wells in King and Queen County.

Location	Depth of well (Feet)	Water bed	Quality of water
Biscoe	10-50	Clay, sand and gravel	Soft
Box	30-75		Soft
Carlton's Store	20-60	Sand	Soft
Cologne	20-50	Sand	Soft
Cumnor	20-40	Sand and marl	Soft to hard
Dragonville	10-40		Hard
Edna	15-50	Clay and sand	Soft and hard
Elsom	30-40	Gravel and sand	Slightly hard
Favor	30-50	Marl	Hard
Indian Neck	30-50	Sand	
Little Plymouth	25-40	Sand	Hard to soft
Plainview	20-30	Sand and marl	
Shackelford	14-24	Gravel	Soft to hard
Shanghai	15-25	Sand	Soft
Stevensville	22-45	Marl and sand	Hard

At Edna the deeper wells go through soil, yellow clay, and thin beds of white and yellow sand to about 35 feet, finding water in white sand and small gravel below iron crusts.

At Favor the average section of 35-foot wells shows red and yellow loam, black "fullers earth," "rock," and shell marl; while at Plainview wells go through loam, clay, white sand, and fullers earth, below which is shell marl.

Conclusions.—Artesian water of good quality can be had under the whole of King and Queen County, but flows can not be expected at elevations of over 30 feet above tide. In places where the interference of wells has resulted in diminished yield, more water under higher heads can be had by going deeper. Places on high ground can avail themselves of the soft, germ-free artesian waters by pumps, but at elevations above 50 feet the wells should be of sufficient diameter to permit the use of pump barrels inside the casing.

KING GEORGE COUNTY.

General description.—King George County, formed from Richmond County in 1720, occupies the west end of the Northern Neck, the peninsula between Potomac and Rappahannock rivers. The county contains no large towns and no large villages. Some of the farms are owned by men of wealth who are remodeling the old mansions and installing water supply plants drawing on artesian flows.

Lying near the western edge of the Coastal Plain, and having tidal rivers on two sides, King George County has greater relief than most counties of Tidewater Virginia. As a rule the divide between the rivers is rather narrow, and is much dissected; it comprises portions of the Lafayette and Sunderland plains. The Lafayette plain has an elevation of 220 feet near Boscobel farm. King George Courthouse stands on the Sunderland plain at an elevation of 130 feet.

Geology.—Potomac, Pamunkey, and Chesapeake deposits underlie King George County; the first are not exposed, but the Pamunkey clays and greensands are exposed along Potomac River from the county line to Mathias Point, and along Rappahannock River from 10 miles below Fredericksburg to 4 miles below Port Royal. At the western side of the county the Pamunkey beds rise 125 feet above tide level; at the eastern side their surface is just below tide level. Their total thickness is 200 to 250 feet, and the Potomac-Pamunkey contact dips east 12 to 25 feet to the mile, its depth below tide varying from 50 to 220 feet.

The Calvert formation of the Chesapeake contains much diatomaceous material, especially in the southeast corner of the county near Wilmont Landing on the Rappahannock, where dry fragments of the light-colored diatomaceous clays float when they fall into the river from the conspicuous bluffs.

The Chesapeake sands, clays, and marls are mantled by the buff and yellow Lafayette and Columbia loams with beds of sand, gravel, and cobbles. Boulders 5 feet or more long are found in the lower terraces.

UNDERGROUND WATERS.

Distribution and quality.—The waters in the Columbia sands vary in quality from clear and soft to irony and hard. Although the Potomac sands underlie the whole county, and undoubtedly contain much water, few wells have been sunk to them. The basal sands of the Aquia formation of the Pamunkey contain supplies of soft water. The Chesapeake, as it lies above sea level, contains no sands that yield flows. The shallow Chesapeake waters are generally hard.

Springs.—Because of the dissection of the surface the county contains many springs, mostly of small size. A few are used for domestic supply. None of commercial importance has been reported.

Wells.—Dug wells with wood lining are the main source of domestic supply. Because of imperfect drainage, wells located on the lower and flatter terraces are particularly liable to contamination by surface water, and some of the backyard wells with decayed lining, through which all manner of filth drips at every rain, are a continual invitation to visitations of typhoid fever. Driven wells are much preferable from a sanitary standpoint, and the deep flowing wells are inexpensive in comparison with the security they give.

LOCAL SUPPLIES.

Rappahannock River.—Two miles east of Sealston is a 250-foot flowing well drawing on Potomac beds, owned by John Curtis. It is on a terrace at an elevation of about 35 feet above tide, and flows two-thirds of a gallon per minute. It is noteworthy for showing variations of flow, due to fluctuations of atmospheric pressure, as stated on page 38. The water, used for drinking, is not so soft as the Pamunkey flows, but is of excellent quality. No record was kept of the formations penetrated; the well was driven to 247 feet and drilled below. The flow is from "quicksand."

At or near Port Conway are several flowing wells drawing on the sands at the base of the Pamunkey or on Potomac sands. One supplies water for

a canning factory; another at the residence of R. V. Hunter is harnessed to a small ram that supplies the house; and a third at Oakenbrow farm, owned by Dr. J. H. Low, flows only about 2 gallons per minute at the level of the terrace on which it stands, but by a gasoline engine and pump 200 gallons per minute can be forced to a tank at the residence, on a bold head-land of the Sunderland terrace, 100 feet above the well.

The character of the material penetrated at Port Conway is indicated by the following generalized section:

Record of well of R. V. Turner, Port Conway.
(Authority, O. D. Hale, driller.)

Material	Thickness (Feet)	Depth (Feet)
Sand and gravel	12	12
Light and dark clay (blue and lead-colored)	212	224
Sand; water-bearing	8	232

The flows of the Port Conway wells are clear and soft. The water has a slight odor of "sulphur" when fresh from the well. (For field assays see table 8.)

The exact depths of the wells at Wilmont Landing could not be ascertained, but they probably tap the sands near the base of the Pamunkey about 275 feet below sea level.

On the wide terrace along Rappahannock River, near Sealston, is a considerable number of driven wells. From one the following record was reported:

Record of well of Frank Taylor, 2 miles south of Sealston.

Material	Thickness (Feet)	Depth (Feet)
Red loam	3	3
Red clay	3	6
Fine red sand	6	12
Fine gravel	4	16
Gravel and small rock	2	18
Boulders and cobbles	3	21
Marl, black sand		

This section is said to be characteristic of driven wells in the vicinity.

Potomac River.—Several flowing wells have been drilled along Potomac River from Chatterton east. The waters are from near the base of the Aquia formation of the Pamunkey, or from the Potomac.

A well on Mathias Point is reported to have shown the following section:

Record of well of C. H. Pemberton, Mathias Point.

Material	Thickness (Feet)	Depth (Feet)
Sandy clay	30	30
Black shell marl	35	65
Red clay with shells	56	121
Gravel and sand	20	141
Rock and clay	30	171
Blue clay	30	201
Sandstone and clay; stone at 227 feet, water at 236 feet.....	35	236

This well has only 16 feet of casing, but a 1-inch pipe runs to the bottom. The water, soft and clear, is used for household purposes. A field assay of a sample is given in table 9.

Near Pluck, Dido, and Vivian are several flowing wells that were drilled at oyster and fish-packing houses. The reported depths range from 175 to 300 feet, but most of the wells probably draw on the Aquia sands. A flowing well near Pluck is but 50 feet deep, and its irony water evidently comes from a bed high up in the Nanjemoy.

At King George Courthouse are 7 or 8 dug wells, 40 to 50 feet deep, that get water from yellowish sands at the base of the Sunderland formation, or at the top of the Chesapeake beds. The quality is fair. Conditions at some of the settlements dependent on dug wells are shown below:

Details of some dug wells in King George County.

Location	Depth (Feet)	Water bed	Quality of water
Edgehill	25-60	Sand	Soft
Hampstead	60-100	Clay and sand	Good in deep wells
Passapatanzy	18-90	Clay, sand and marl	Hard in deep wells
Rollins Fork	40-65	Gravel	Soft
Shiloh	30-50	Sand and marl	Soft

Near Hampstead dug wells penetrate 25 feet of loam and clay, 15 feet of gravel and sand, and find water on the top of the Chesapeake marl. Here and at a number of other points in the county digging into the dark bluish, sandy clay or "marl" of the Chesapeake obtains a scanty supply of water of poor quality for domestic use.

Conclusions.—Good artesian water, soft but alkaline, that will rise 20 to 30 feet above sea level can be had at nearly all places in the county.

KING WILLIAM COUNTY.

General description.—King William County lies between Mattaponi and Pamunkey rivers, extending some 30 miles northeast of the point where they unite to form York River. At the junction of Pamunkey and Mattaponi rivers is the city of West Point, with a population of 1,397 in 1910. The county is rather sparsely inhabited and contains few large villages, some of the larger being Lester Manor, Cohoke, King William, and Aylett.

Topography.—The topography is diversified. The northwestern portion of the county approaches the western edge of the Coastal Plain, and the Lafayette terrace extends into it, but most of the surface is formed by the Sunderland terrace, which is deeply cut by stream valleys. Along both Pamunkey and Mattaponi rivers are expanses of the Wicomico and lower terraces, especially the Wicomico, which contain much good farming land. The elevation of the Lafayette terrace is about 200 feet, while that of the Sunderland is 180 feet in the northwestern part of the county, and 110 feet in the southeastern part. The Wicomico terrace varies in elevation from 50 to 90 feet, and the other lies below 60 feet.

Geology.—Potomac, Pamunkey, and Chesapeake beds underlie the county, but the Potomac beds are not exposed. The top of the Potomac may be 200 feet below tide level on the northwestern boundary of the county, and 400 feet below at West Point.

The greensands of the Aquia and Nanjemoy formations of the Pamunkey group outcrop along the Pamunkey River from the west end of the county to Piping Tree Ferry, where they disappear below the tide level. Above the Pamunkey are Chesapeake sands and clays more or less covered by Lafayette or Columbia gravels, sands, and loams. The base of the Chesapeake is 20 feet above tide level on the Pamunkey near Hanover Courthouse, and 180 feet below at West Point. The base of the Pamunkey group is 150 to 350 feet below. In the Wicomico and Talbot formations of the Columbia, particularly along Pamunkey River, are many large sub-angular boulders.

UNDERGROUND WATERS.

Distribution and quality.—Ground water that supplies springs and shallow wells is found in the Pamunkey in the western part of the county, in the Chesapeake in the eastern, and in the Lafayette and Columbia terrace materials. Its quality generally is excellent. Artesian waters underlie the whole county. The Chesapeake and Pamunkey groups furnish fine flows in the eastern part of the county. At the western end of the county, where the Chesapeake lies above tide level, water that will rise above tide level can be had from the Potomac, but few wells have been drilled to it.

The Pamunkey and basal Chesapeake waters differ but little, being delightfully soft, and more or less alkaline from the presence of bicarbonate of soda; some are slightly sulphur-bearing.

Springs.—There are many springs in King William County, but few that are of especial note and none of commercial importance.

Wells.—Dug wells are the main source of supply over most of the county; but, except Southampton County, there is no county in Tidewater Virginia having more drilled wells, as a large number have been sunk in the city of West Point. The drilled wells are nearly all of small diameter and the great majority draw on Calvert beds. The flows of properly drilled and cased wells are generally free, but the waters do not rise more than about 35 feet above tide level, hence there are not many wells on the 30 to 50 foot terrace along Pamunkey River above Elsing Green.

LOCAL SUPPLIES.

Aylett, on Mattaponi River, noted in colonial times for its export shipments of corn, has only three dug wells, which are from 20 to 65 feet deep; two sunk over 60 feet obtained scanty supplies of hard water. Several families use the water from a spring just below the terrace on which the village stands.

Two artesian wells on the terrace, 25 feet above the river, get clear, soft water in basal Pamunkey beds at 160 feet below mean high tide. One of these wells, owned by J. C. Fox, was put down at a total cost of but \$40. The small flow, one-third of a gallon per minute, is due to the elevation, and possibly also to there being only 20 feet of 2-inch casing in the well, but the flow suffices for domestic purposes and for 20 head of stock, the overflow from a tank at the well being piped to the barn. This well is said to have gone through 20 feet of Columbia loam and sand, some 60 feet of "fullers earth" or fine dark clay, and then through beds of shell marl and rock, five or six "rocks" in all, before finding water in a gray sand. No flows were found above the one used, and the head of this is about 35 feet above mean high tide in the Mattaponi. A complete analysis of a sample of water from this well appears in table 8.

The other well, owned by Dr. J. B. Moore, also has only 20 feet of casing, but a $\frac{3}{4}$ -inch pipe goes to the bottom of the water-bearing sand at 190 feet.

West Point is situated on low land, mostly not over 15 feet high. Along the rivers were formerly open marshes. Owing to the low elevation, a water table near the surface, and a sandy soil, the dug wells or driven pumps

which were once the chief source of supply, were particularly liable to pollution, and the city once had a reputation for malaria and typhoid fever. Since the introduction of artesian water there has been a great improvement in public health, and local physicians claim that cases of typhoid fever originating in the city are practically unknown. The total number of drilled wells may be 300. They range in depths from 110 to 360 feet, but all draw on one or more of three water beds; the first at 110 to 120 feet, the second from 160 to 170 feet, and the third from 320 to 340 feet. The first, low in the Chesapeake, yields scant supplies of water having a decided sulphur odor and is now little used. The second, in basal Chesapeake beds, yields water that has a very slight sulphur odor, and to it the great majority of the wells in the city have been drilled. The third, in the Pamunkey, yields water much like that from the second, but it has been tapped by comparatively few wells. The two upper horizons once had strong heads, 15 to 25 feet, but the drilling of many poorly cased wells, and the constant flow from wells near the shore but a few feet above tide, have greatly lowered the heads in both sands, so that wells to the 120-foot sands will not flow at more than 4 or 5 feet above tide, and those to the 165-foot at not over 10 feet. This loss of head through interference has been discussed on page 71. Wells driven to the third flow are put down with care, and are usually cased to the bottom. The head of this flow is about 30 feet above tide.

All the West Point wells feel the rise and fall of the tide, and many flow at high water and do not at low water. The largest well at West Point was put down for the Southern Railway. The record was destroyed by a fire, and detailed records of the many small wells have not been kept.

The following generalized section was given by one of the most careful drillers in the city:

Generalized section at West Point.

(Authority, J. V. Bray, driller.)

Material	Thickness (Feet)	Depth (Feet)
Loam or marsh mud	10	10
Fullers earth	100	110
White sand and shell, water in shells	11	121
Shells, no sand	5	126
White sand	20	146
Greensand	6	152
Shells, second flow at 160 feet	8	160
Thin bed of reddish clay.....	1	161
Black sand and gravel, third flow in gravel at 320 feet.....	160	321

Another record of a well drilled near the post-office is as follows:

Record of well of Wm. Wheeler, West Point.

(Authority, J. Frank Smith, driller.)

Material	Thickness (Feet)	Depth (Feet)
Fullers earth	90	90
Fine white sand, small stream of sulphur water at 112 feet...	35	125
Fullers earth	15	140
Shells, with good water at 150 feet	40	180
Black sand with "beautiful gravel" at 316 to 320 feet.....	140	320
Rocks with sand below	80	400

Artesian water is used at West Point for all domestic purposes and for boiler supply. The large number of wells drilled and their low cost, drillers asking but \$50 for a 2-inch well to the second flow, delayed the installation of a public waterworks system. The present system, described on page 78, distributes water from wells tapping the 325-foot flow. The bacterial purity of this water is beyond question, and the quantity obtainable with ordinary care in development should be sufficient for years to come. Field assays of the water from several wells in West Point, and a complete analysis of water from the 165-foot flow, taken from a well at Beech Park, the property of the Southern Railroad Co., are given in tables 8 and 9. The water is notable for the percentage of sulphates.

The water from both the 165-foot and 325-foot wells has a tendency to foam in a boiler, and works best in horizontal boilers. It is, nevertheless, used in vertical marine boilers by tugs and other river craft. With a horizontal boiler it is the custom to blow off some water every few days to prevent the water from becoming too concentrated. The artesian water is much used at the large oyster houses for washing oysters. For this purpose it is most admirably suited, its bacterial purity making it especially desirable for washing shucked oysters.

In or near Lester Manor about 10 drilled wells find flows in fine to coarse Pamunkey sands that contain much dark green glauconite, and many shell fragments, a greensand marl. The following generalized record was furnished from memory:

Record of well of John G. Robins, 3 miles west of Lester Manor.

(Authority, H. E. Shrimp, driller.)

Material	Thickness (Feet)	Depth (Feet)
Clay	60	60
Shell rock	50	110
Fullers earth	90	200

The water bed at this well is a medium quartz sand containing much glauconite.

On Pamunkey River above Lester Manor, wells have been driven at Elsing Green, near Palls, and southeast of Manquin. The driller gave from memory the following record of one of the wells at Elsing Green:

Record of well of Roger Gregory, at Elsing Green.

(Authority, H. E. Shrimp, driller.)

Material	Thickness (Feet)	Depth (Feet)
Loam and gravel, surface water.....	10	10
Bluish sandy clay	50	60
Rock, full of fossil shells	30	90
Bluish slightly sandy clay, lighter than clay above, water at bottom	180	270
Soft greenish rock, sandy in places, no shells in it.....	30	300

A sample from a reported depth of 300 feet was a coarse quartz sand containing much glauconite.

The wells southeast of Manquin may draw on the Potomac flows; one of these, owned by C. B. Chapman, 6 inches in diameter and 237 feet deep, yields 6½ gallons per minute of soft water that is piped to half a dozen places about the farm buildings, and is used in steam boilers (for analysis see table 10). The following record was furnished from memory by Edward Williams:

Record of well of C. B. Chapman, 1 mile south of Manquin.

Material	Thickness (Feet)	Depth (Feet)
Loam, clay and sand	10	10
Marl and greensand with shells	175	185
Stiff blue clay	40	225
White sand with water	12	237
The water sand is medium coarse and contains flakes of mica.		

Several flowing wells have been drilled at Cohoke to the Pamunkey horizon tapped at Lester Manor. The driller gave the following record of one:

Record of well of J. N. O. Johnson, near Cohoke.

(Authority, H. E. Shimp, driller.)

Material	Thickness (Feet)	Depth (Feet)
Clay and sand	100	100
Shell rock	52	152
Hard rock	88	240
Quicksand, water		240

The water bed is a medium coarse quartz sand containing much dark green glauconite, and many fragments of shells.

On Mattaponi River opposite Walkerton are wells which draw on horizons tapped at Walkerton, mentioned in the description of King and Queen County.

An attempt was made about 20 years ago to obtain artesian water at King William Courthouse. A well some 350 feet deep found water, but, since the courthouse stands on the Sunderland terrace at an elevation of 135 feet above tide water, no flow was obtained and the well was abandoned. It is stated that the water rose to within 17 or 18 feet of the surface, but since the heads of the flows at Walkerton, a few miles away, are under 40 feet, this seems altogether unlikely.

At some of the villages in King William County which depend on dug wells conditions are summarized as follows:

Details of dug wells in King William County.

Locality	Depth of wells (Feet)	Water bed	Quality of water
Beulahville	19-75	.....	Hard
Duane	20-40	Sand and gravel	Fair
Enfield .....	.....	.....	.....
Lanesville	15-25	Clay and sand	Soft
Mangochick	20-40	.....	.....
Manquin	20-45	Sand	Soft
Sykron	15-80	Clay and sand	Soft to hard

Conclusions.—Enough wells have been driven to show the entire practicability of getting flows of soft alkaline water at elevations of less than 35 feet over nearly all of the eastern part of King William County. Where wells have been closely driven and have been allowed to flow without restraint, as at West Point, resulting in general loss of head, more abundant flows under higher head of as good water can be had by going deeper.

On high ground, as at King William Courthouse, flows are impossible, but the artesian water can readily be obtained by the use of deep well pumps. At King William a well 450 feet deep will reach the sand supplying the Walkerton wells, but the water from these will not rise to 50 feet of surface.

LANCASTER COUNTY.

General description.—Lancaster County, formed in 1651, lies on the north side of Rappahannock River near its mouth, occupying the southern

part of the end of the peninsula between Rappahannock and Potomac rivers. The principal settlements are Irvington and Weems.

The topography, though the greater elevations are less than in counties to the west, shows considerable variety. A high terrace with an undulating surface cut by V-shaped creek valleys extends eastward nearly to Kilmarnock. Lancaster Courthouse stands on it. The maximum elevation in the northwest end of the county is 90 feet. Lower terraces are traceable along Rappahannock River and face Chesapeake Bay. The drainage is mostly to the Rappahannock, the county line on the northeast following the Potomac-Rappahannock divide. Along the bay coast are many tidal inlets and the shoreline is extremely irregular.

Geology.—Though the sandy loams of the Columbia (Pleistocene) formations cover most of the surface, shell beds and sands belonging to the St. Mary's formation of the Chesapeake (Miocene) group are exposed in headlands along Rappahannock River and in creek gullies.

The bottom of the Chesapeake lies 360 feet below tide level at the Richmond County line and nearly 600 feet below at Windmill Point. So far as can be determined from well records the underlying Pamunkey (Eocene) group is about 100 feet thick, its base lying 480 feet to 700 feet below tide. At Windmill Point the top of the Potomac group (Lower Cretaceous) is fully 800 feet below sea level, and crystalline bed rock over 1,000 feet deeper.

UNDERGROUND WATERS.

Distribution and quality.—The Columbia sands and the top beds of the Chesapeake contain much ground water; the quality differs from place to place, here soft, there hard or irony. On low tracts near tidal inlets the ground water is at times brackish.

Artesian waters underlie all the county. The water bed most widely developed is a coarse sand in the Calvert formation, lying about 240 feet below tide at Whealton and 320 feet below at Irvington. The water is alkaline, soft, and sulphur-bearing. This sand either thins out or becomes too clayey to transmit water a few miles east of Irvington, and attempts to get water from it have had little success. Flows have been obtained from Pamunkey sands that lie 500 to 700 feet below sea level, and from Upper Cretaceous deposits. The Pamunkey sands, like the Chesapeake, are less freely water-bearing toward the east end of the county.

Springs.—Below the scarp of the high terrace are springs of the usual Coastal Plain type, few of which are of especial importance.

Wells.—Open dug wells, driven wells, and drilled wells are in use. The driven wells are mostly in the eastern end of the county, the drilled wells along inlets from Rappahannock River and Chesapeake Bay. Depths of dug wells vary from 8 to 50 feet, of driven wells from 10 to 20 feet, and of drilled wells from 100 to over 500 feet. Dug wells in lowlands in the east end of the county are sometimes salted by high tides.

LOCAL SUPPLIES.

At and near Whealton artesian wells, drawing on the Calvert sands at 240 feet below river level, supply drinking water for 200 people, and are claimed to have effected a marked improvement in the general health. The water is used not only for domestic purposes but also at a tomato canning plant and an oyster packing house. The wells are $1\frac{1}{2}$ or 2 inches in diameter. The flow from one well is fed to a ram with $4\frac{1}{2}$ -foot fall; the ram elevates enough water 40 feet to keep full a tank in a dwelling house.

The following generalized record is reported:

Record of well of Lewis-Lankford-Tull Co., Whealton.

Material	Thickness (Feet)	Depth (Feet)
Sand	22	22
Fullers earth or blue clay	192	214
Rocks and sand, rocks one-half to two inches thick; water at 251 feet	42	256

This well has 214 feet of $1\frac{1}{2}$ -inch casing; the flow is given as 16 gallons per minute at 8 feet above the river.

O. D. Hale, who has drilled many wells along Rappahannock River, reports the following generalized section:

Generalized section at Whealton.

(Authority, O. D. Hale, driller.)

Material	Thickness (Feet)	Depth (Feet)
Sand and light clay	65	65
Fullers earth or blue clay	70	135
Rocks and sand, rocks $\frac{1}{2}$ inch to 6 inches thick	45	180
Clay and sand	93	273
Thin rock, with varicolored sand below, water		273

Essentially the same beds are tapped by wells farther down the river near Monaskon.

Near Bertrand, Millenbeck, Weems, and Irvington, perhaps 30 wells from 270 to 580 feet deep, have been drilled for domestic supply and other purposes. The wells at Bertrand, used for washing oysters and for household supply, get water from sands in the Calvert formation about 265 feet below river level. The water is soft and slightly sulphur-bearing. At Millenbeck and Merry Point the wells reach water of about the same quality at 200 to 210 feet. At Weems and Irvington most people get water from dug wells 15 to 35 feet deep. The towns are on a terrace with maximum elevation of about 30 feet. The wells at Weems go through sandy loams and clays and find water, soft, hard, and irony, at 12 to 20 feet, in a thin sand bed that overlies a black mud or clay. A mile west of Weems a dug well found this black clay 20 feet thick. Near the edge of the terrace at Irvington the dug wells, 25 to 35 feet deep, get soft water. About 70 per cent of the wells in the town are bricked, 20 per cent cased with tile, and 10 per cent with wood. The recent wells are nearly all cased with tile. There are many driven wells in the vicinity of the town, most of them about 20 feet deep. Some wells close to the inlets get brackish water.

The drilled wells near Irvington and Weems penetrate two important water sands, one about 330 feet below sea level in the Chesapeake group (Calvert formation), and the other between 200 and 240 feet deeper in the Pamunkey group. The wells driven to the first sand are $1\frac{1}{2}$ inches in diameter and yield small flows, $\frac{1}{2}$ to $2\frac{1}{2}$ gallons per minute, of soft, alkaline water having a decided sulphur odor; the head is low, possibly 10 feet. A 3-inch well at a fish factory at Irvington and another at a country residence across Carters Creek from Weems get excellent water, under a head of about 35 feet above tide, that has no sulphur odor. The well at the fish factory is said to have flowed 58 gallons per minute at an elevation of about 5 feet when first completed; this flow was cut down to about 40 gallons by screening. The water keeps well in vessels and is said to work well enough in a horizontal boiler, but primes in a vertical boiler. The well on the Francis estate had in 1906 a measured flow of about 35 gallons per minute at 6 feet elevation. It is used for general purposes. Field assays of samples from several wells are given in tables 8 and 9.

The following partial analysis of the water at a 330-foot well at the fish factory in Irvington was furnished.

*Partial analysis of 330-foot well Carters Creek Fish Guano Co.,
Irvington.*

(Analyst unknown)

	Parts per 1,000,000
Calcium carbonate (CaCO_3)	14.0
Calcium sulphate (CaSO_4)	4.7
Magnesium carbonate (MgCO_3)	8.4
Sodium chloride (NaCl)	122.0
Iron oxide (Fe_2O_3)	12.0
Sand, clay, etc.	41.0
Organic matter	68.0

The prices for drilling at Irvington have varied. Some 1½-inch wells to the first flow cost \$100; the 3-inch wells to the deeper flow cost about \$2 per foot.

Along the river below Irvington, at Whitestone and Westland, two attempts to get flows resulted in failure, the drillers not having had strong enough rigs. Northeast of Irvington on inlets from Chesapeake Bay at Chase's Wharf, Ocran, and near Kilmarnock, are flowing wells that get water 400 to 650 feet below tide level in basal Chesapeake and Pamunkey or Upper Cretaceous beds. The water is used for various purposes. The flow near Kilmarnock, when the well was just completed, was given at 140 gallons per minute through a 3-inch pipe. It supplies a fish factory.

A 660-foot well at Ocran yields an alkaline water that is used for boiler and other purposes at a fish factory. A partial analysis made by the Hartford Steam Boiler Insurance Co., and kindly furnished by Lawford and McKim, of Baltimore, Md., showed each 1,000,000 parts of the water to contain 616 parts of total solids, which included 548 parts of readily soluble matter and 56 parts of silica. The soluble constituents were carbonate of soda (large amount), chloride of soda (considerable), and some sulphate of soda and carbonate and chloride of potash.

The following record of a well on Dimer Creek, probably at Chase's Wharf, has been published by Darton.^a

^aDarton, N. H., *Op. cit.*, p. 176.

Record of well on Dimer Creek.

Material	Thickness (Feet)	Depth (Feet)
Tough blue clay, with 3-inch sand bed at 170 feet.....	237	237
Marl with shells and gravel	2	239
Gravel with good supply of water which rises to within 10 feet of surface	2	241
Blue clay	7	248
Rock, underlain by coarse sand mixed with yellow and green clay	2½	250½
No record	2½	153
Clay	132	385
Rather coarse dark sand.....	3	388
Blue clay	47	435
Sand, fairly coarse, dark buff and white below, 7-gallon flow of water	8	443
Hard rock, very rough, porous	21	464
Coarse sand mixed with clay and mica, 5-gallon flow of water	10½	474½
No record	1½	476
Rock, quite hard	3	479
Blue clay and sand	28½	507½

At Lancaster Courthouse, elevation about 75 feet, an attempt to get a flow some years ago naturally resulted in failure. Dug wells in the vicinity of the Courthouse are 30 to 60 feet deep. The following record of the Courthouse well has been published.^a

Record of well at Lancaster Courthouse.

Material	Thickness (Feet)	Depth (Feet)
Bright orange sand, moderately coarse	30	30
Gray sands, moderately coarse with shell fragments.....	45	75
White and yellow sand intermixed, moderately fine.....	40	115
Gray sand moderately coarse, some glauconite grains, few shells and thin ferruginous crusts	45	160
Greenish-gray fine sands, mud with some mica and many shell fragments, some glauconite	20	180
Clay, light brownish-gray in color, few sandy streaks, shell fragments	70	250
Clay, light greenish-gray in color	50	300

Some data reported regarding the shallow wells at a number of villages are summarized thus:

^aDarton, N. H., Op. cit., p. 176.

Details of shallow wells in Lancaster County.

Location	Depth of well (Feet)	Water bed	Quality of water
Alfonso	24-60	.....	Soft and hard
Fisherman	8-15	Sand	Brackish
Litwalton	65-70	.....	Soft
Millenbeck	10-30	Sand	Poor
Monaskon	10-70	.....	Soft and hard
Ottoman	10-60	Shallow, sand; deep, clay and rock	.....
Rehoboth Church	10-90	.....	Shallow, poor; deep, good
Westland	5-15	Clay and sand	Soft or brackish
Whitestone	8-18	Shallow, sand; deep, clay	Good, soft

Conclusions.—While the mid-Chesapeake sands tapped by the 330-foot wells at Irvington can not be depended on for flows or satisfactory yields farther east, carefully drilled wells can get plenty of water at greater depths even as far east as Windmill Point. There is nothing to show that the water will be too highly mineralized for general use. At points above Irvington where flows from the first sand have been reduced by drilling several wells within a small radius, more water, probably of better quality, can be had by going deeper. Pumping will be required to get water at Lancaster Courthouse from either the Chesapeake sands, about 400 feet below the Courthouse, or the Pamunkey sands 200 feet deeper.

MATHEWS COUNTY.

General description.—Mathews County ranks next above Alexandria County in small area and in density of population. It occupies the peninsula between Pianketank River, Chesapeake and Mobjack bays, and has an extremely irregular outline. There are many villages but no incorporated towns.

The surface of Mathews County is monotonously level, nearly all of it lying within the Talbot plain.^a From a maximum elevation of about 30 feet near the Gloucester County line the surface gradually slopes east and south to tide level. Along the eastern shores wide stretches of salt marsh fringe the inlets, and the surface slopes so gradually below sea level that heavy easterly gales drive the bay water far inland.

^aThe writer believes that most of the surface of Mathews County forms part of a terrace that is to be correlated with the Pamlico terrace of North Carolina.

Geology.—In the northwest part of the county gray Chesapeake sands of the St. Mary's formation are here and there exposed in the bluffs along Pianketank River; elsewhere in the county only Columbia or Recent material is visible. Near the west side of the county yellow buff and reddish loams, seen in road cuts and ditches, overlie more sandy beds. Eastward these bright-colored loams grow thinner and disappear, the sands become marly, and along the bay front mud and marl predominate. Near Port Haywood and elsewhere, dark, ill-smelling mud containing tree roots is found at depths of 15 to 25 feet and deeper, and the thickness of Columbia material may be 50 feet.

The bottom of the Chesapeake lies 500 to 600 feet below the surface, and the bottom of the Pamunkey 100 feet deeper. Evidence as to the presence of the Upper Cretaceous is lacking, and nothing is known of the Potomac. Crystalline bed rock is probably 2,000 feet below the surface.

UNDERGROUND WATERS.

Extent and character.—Because of the slight elevation and the nature of the beds the abundant shallow waters in the Columbia sands are not satisfactory at many points in the county, being high-colored, ill-smelling, and even brackish. In the western part of the county near North River dug and driven wells go through a foot of soil, 12½ feet of "yellow" clay, and 4 feet of red clay, finding water in sand below. On ground 20 feet or more high, the water is soft and sweet, while on flats the water is poor. Many of the shallow wells on higher ground go dry in times of drought. Waters from sands at a depth of 100 feet or so vary in quality and in the yield to driven or drilled wells; in places these sands afford plenty of excellent water, in places they supply but little, and this is irony or otherwise objectionable.

Artesian waters under heads sufficient to give surface flows underlie most of the county, but those so far found are not satisfactory. The Chesapeake and Pamunkey, beds which afford such abundant supplies in counties to the west, apparently are too fine-grained under Mathews County to transmit water readily; the waters are under lower head and are more sulphur-bearing and irony.

Springs.—Except in the western part of the county there are few springs large enough to be used for household supply. At Dixie, on Pianketank River, however, several seeps and springs emerge from a bluff of loam and sand. Their total volume is problematical, but two flows, one about 10 feet above the other, caught by wood basins, supply a saw-mill and

a tomato canning factory on the shore below. The water is soft, free from iron, and works well in a boiler. Near Hudgins are two springs used for domestic supply and for stock. One owned by N. C. Miller is said to be used by neighbors when their wells go dry.

Wells.—There are many driven wells in the county, conditions favoring their use. In places, however, the fine sands of the water-bed clog pipes and cut the valves of pumps, and dug wells are favored.

LOCAL SUPPLIES.

At Mathews most of the water is from dug wells 8 to 12 feet deep, which, as the surface elevation is about 6 feet, seldom go dry, though wells close to the river get brackish after unusually high tides. Some of these wells are liable to pollution by surface drainage.

Besides the dug and driven wells there are a few cisterns in the village. Several attempts to get artesian water at the Courthouse have not resulted satisfactorily. The last well found water between 100 and 150 feet, and, according to the driller, a stronger flow at 817 feet. The water has a head of only 6 feet, and the yield in September, 1906, was 1 gallon per minute at an elevation of 4 feet. The water has a decided sulphur odor and is little used. The flow is said to have nearly ceased during the summer of 1905. The low head, the temperature, and the quality of the flow, as shown by the field assay in table 11, indicate that much of the water may come from the higher sands of the Chesapeake rather than from Potomac strata.

Near Port Haywood several drilled wells have found at about 100 feet water that is considered soft, and is used for household purposes or for boiler supply. It comes from sands high in the Chesapeake group.

Over much of the county, dug wells fill nearly to the top in wet weather. Where the water is high in iron, ill-smelling or salty, cisterns are much used. On Gwynn's Island, where about 600 people live, wells average only 7 to 9 feet deep.

Particulars regarding dug and driven wells at a number of places are thus summarized:

Details of dug wells in Mathews County.

Location	Depth (Feet)	Water bed	Quality of water
Blakes	8-16	Sand	Soft
Cardinal	8-16	Sand	Shallow wells, soft, brackish; deep wells, hard.
Cobbs Creek	8-10	Sand	Fair
Diggs	7-12	Sand	Soft
Dixie	12-40	Sand and marl	Soft
Grimestead	7-10	Sand	Good
Hudgins	6-10	Sand and clay	Poor
Mathews	7-12	.....	Shallow, soft; deep, brackish.
New Point	5-8	Sand	.....
North	6-15	Clay and sand	Hard, brackish
Port Haywood	7-25	Mud, shell beds, and sand.	Shallow, soft; deep, hard, and irony.
Susan	6-12	Clay and sand	Shallow, soft; deep, hard.
Tabernacle	6-8	Marl	Good
Williams Wharf	6-12	Shells and sand	Fair

A 70-foot driven well at Port Haywood entered "blue mud and shells" at about 20 feet and struck "soft rock" at 40 feet, but found no water worth mentioning. A driven well 110 feet deep at Fitchett's found water too salty for use. The pipe was pulled back to 50 feet and water was obtained that though a little brackish could be used in a boiler.

Conclusions.—While the Chesapeake beds under eastern Mathews County are apparently fine and clayey, small flows of hard or iron-bearing water may be had from discontinuous sand beds near the top of the group. The prospects of obtaining water of good quality from the Pamunkey beds or below at points east of Mathews Courthouse are doubtful; the odds favor highly mineralized water containing salt, iron and sulphur. Near the Gloucester County line prospects are much better.

MIDDLESEX COUNTY.

General description.—Middlesex County, formed from Lancaster in 1845, lies on the south bank of Rappahannock River, near its mouth, and north of Pianketank River.

The topography is diversified. The Sunderland terrace, elevation 90 to 120 feet, forms the divide between Rappahannock and Pianketank rivers, and is deeply cut by creeks flowing to the Rappahannock. Along

this river a bold scarp marks the drop from the Sunderland to the Talbot terrace, and at the east the Wicomico terrace terminates in the scarp that is traceable across the counties south to the North Carolina line. In Middlesex, as in Essex County, to the northwest projecting headlands of the highest terrace give magnificent views of Rappahannock River valley.

Geology.—The Columbia loams, clayey and bright-colored on the high terraces, and of subdued tints along the low terraces, mantle the surface. No beds older than those of the Chesapeake group (Miocene) outcrop anywhere in the county. Shell beds and gray sands of the St. Mary's formation are exposed beneath Columbia sands in low bluffs along Rappahannock River and in the gorges of the larger creeks. The Chesapeake-Pamunkey contact lies at about 300 feet below sea level at the northwest end of the county, and about 600 feet below at Stingray Point. The thickness of the Pamunkey may be 100 to 150 feet. It is probable that marine Cretaceous beds underlie most of the county, but they can not be sharply differentiated on the evidence of such well records as are available. There are no records of wells sunk to Potomac beds, but it is likely that at Urbanna the top of the Potomac group is over 800 feet below sea level.

UNDERGROUND WATERS.

Distribution and quality.—Both the Columbia formations and the top-most beds of the Chesapeake contain ground water. The quality shows the usual variations. The artesian waters in the lower Chesapeake and in the Pamunkey sands are soft, but as a rule more highly mineralized than in Essex County. East of Urbanna the Chesapeake and Pamunkey water beds become gradually finer, the heads of the flows decrease and the mineralization of the water increases. A characteristic of the Chesapeake flows along Rappahannock River is a decided sulphur odor; this soon disappears, but makes the water when fresh from the well offensive to some persons. The deeper flows seem freer from sulphur. The heads of the different flows show local variations, but as far east as Urbanna properly driven wells, where there is no interference, yield waters from basal Chesapeake (Calvert) beds that rise 15 feet above mean high tide; the Pamunkey flows rise 10 feet higher.

Springs.—Along the gorges of the creeks that flow into Rappahannock River, near the foot of the Sunderland scarp, and in Pianketank River valley, there are many springs. Some are of considerable size, flowing 10 gallons or more per minute. A few are used for household supply. None is of commercial importance.

At the head of a small run on the old Fauntleroy place near Saluda, now owned by J. C. Gray, several springs issue from above dark sandy clay, or from marl beds, belonging to the Chesapeake group. Part of the flow of the highest spring supplies a ram that forces water to a tank in the house, 300 feet distant.

Another spring that gushes from a marl bed on a steep slope to Pianketank River, at the residence of J. E. Blakey, 3 miles southwest of Saluda, supplies the house and barn by means of a ram.

Wells.—Dug wells, the chief source of water supply, vary greatly in depth. Most of them have no lining except plank near the bottom; a few are bricked, and a few cased with tile. In places along the lowest terrace there are drilled and driven wells, nearly all of small diameter. Dug wells, bricked, have been completed for 40 cents per foot.

LOCAL SUPPLIES.

Urbanna in 1906 had no public waterworks, but water from a number of artesian wells was given away by the owners to all persons desiring it. A well intended to supply water for a distribution system was drilled to a depth of 590 feet. The record is of interest as the well is one of the few that have been drilled below 500 feet in this part of the Coastal Plain.

Record of waterworks well, Urbanna.

(Authority, R. H. Milligan, driller.)

Material	Thickness (Feet)	Depth (Feet)
Clay, sand, and gravel	25	25
Marl	175	200
Hard, bluish black clay	20	220
Sand, very light flow of sulphur water, flow not tested.....	18	238
Rock	1	239
Marl	21	260
Thin rocks, 6 to 8 inches thick, in marl	30	290
White chalky deposit, "neither sand nor clay".....	2	292
Marl ^a	108	400
Bluish clay	45	445
White sand, very light flow of sulphur-bearing water.....	3	448
Coarse gray sand and white gravel	7	455
Hard sand, no water	10	465
Bluish clay	27	492
Sand, water-bearing, flow small but not tested.....	8	500
Marl	22	522
Hard red clay, "red as paint"	18	540
Softer pink and brownish clay which caved easily.....	7	547
White loose sand with thin crusts, sand often in little balls easily crushed by fingers, no clay; good flow of water, volume not tested	42	589

^aBones and small teeth are reported to have been struck at 400 feet in blue marl.

This well went through both Miocene and Eocene into Upper Cretaceous beds. The quality of the water from the last flow is said to have been excellent. The well, when seen by the writer, was flowing 3 gallons per minute from the sand at 492 feet; the bottom flow had been shut off by the clay beds caving.

A well near by passed through the following strata, according to the driller:

Record of well of G. W. Hurley, Urbanna.

(Authority. R. H. Milligan, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil, sand, and clay	25	25
Black mud	100	125
Marl	96	221
Rock	2	223
Coarse sand, flow of sulphur water, volume not tested, possibly 1 gallon per minute at surface.....	7	230
Soft marl, shelly at top	40	270
Light marl, containing thin layers of rock.....	15	285
Green marl	5	290
Black sand, not water-bearing, and marl.....	30	320
Soft blue clay	132	452
Sand, water-bearing; flow not tested	1	453
Rock	1	454
Sand containing bits of lignite, water-bearing; flow at 3 feet above high tide 105 gallons per minute through a 3-inch pipe, head over 30 feet	22	476

The water from this well, together with that from several wells tapping the sulphur water at 225 feet, is used at an ice plate. It is said to work better in a boiler than the water from the 225-foot wells, having less tendency to foam. Like practically all the deep artesian waters of the Virginia mainland, it contains little volatile organic matter, and hence makes excellent ice.

Other flowing wells at Urbanna are said to range in depth from 227 to 290 feet, but probably draw on sands 220 to 235 feet below high tide level. One of the shallowest, that of G. V. Wagenen, was sunk by the owner in less than a day, no rock being encountered. The flow at first was 5 gallons per minute, but had fallen to about 2 gallons in 1906. The water is used at a canning factory. The well of the Urbanna Manufacturing Co. is worthy of note as it is used to supply the cottages of employees, the water being pumped to an elevated tank. The depth of this well could not be ascertained, but the water has a decided sulphur odor and probably comes from the sand at 220 to 235 feet. Field assays of samples from various wells at Urbanna are given in tables 8 and 10.

Above Urbanna, along Rappahannock River, artesian wells have been drilled at Bayport and several other places. The reported depths of the Bayport wells vary from 260 to 300 feet, and the water probably comes from Calvert, basal Chesapeake, sands. The water is used for domestic purposes and for washing oysters. The following generalized section is reported:

Record of well of Bland Brothers, Bayport.

(Authority, O. D. Hale, driller.)

Material	Thickness (Feet)	Depth (Feet)
Sand	24	24
"Fullers earth" or blue clay.....	176	200
Alternating strata of rock and sand, rock layers from ½ inch to 10 inches thick, water at 242 feet.....	48	248

The well has 218 feet of 1½-inch casing. The reported flow is 16 gallons per minute at 7 feet above Rappahannock River.

A driven well at Sandy Bottom, in the east end of the county, found water in deep Columbia beds. The following record is reported:

Record of 78-foot driven well of D. A. Taylor, Sandy Bottom.

(Authority, D. A. Taylor, owner.)

Material	Thickness (Feet)	Depth (Feet)
No record	30	30
Old wood and shells, blue mud	10	40
White sand	½	40½
Blue mud	32½	73
Gravel, principal water bed	2	75
Blue mud	25	100

Dug wells in Middlesex County, as previously noted, differ greatly in depth and in quality of supplies. Wells on high ground near a terrace edge go deep, usually yield soft water, and seldom if ever, go dry; while wells away from the terrace edge are shallower and more liable to go dry. Many wells go through the Columbia sands and get hard water from the Chesapeake shell beds. Conditions reported from various places in the country are briefly summarized thus:

Details of dug wells in Middlesex County.

Location	Depth (Feet)	Water bed	Quality of water
Butylo	40-60	Sand and clay	Good
Church View	20-50	Sand	Fair to good
Dew	15-45	Sand and marl	Hard or irony
Freeshade	12-40	.....	Fair
Enoch	10-16	Sand	Hard
Lot	16-35	Sand	Soft to hard
Ruark	10-35	Clay	Shallow, poor; deep, good.
Saluda	40-55	Marl and red clay	Hard and soft
Streets	22-60	Sand	Soft
Urbanna	18-30	Marl	Hard, brackish
Warner	8-32	Red clay	Shallow, poor; deep, good.
Waterview	15-60	Shallow, sand; deep, rocks.	Fair to good
Wilton	15-60	Shallow, sand, deep, rocks.	Fair to good

Conclusions.—Over most of Middlesex County dug wells will remain the chief source of supply because of the cost of developing the artesian sands. Plenty of soft alkaline water can be had from the latter, and if the higher sands at any point yield insufficient flows better yields can be had by going deeper. From none of the sands are heads of more than 35 feet above tide to be expected. Hence wells of sufficient diameter to permit the use of deep well pumps will be required to supply villages on high ground. At Saluda, elevation about 75 feet, flows are impossible; the water will rise to about 40 feet of surface.

NANSEMOND COUNTY.

General description.—Nansemond County lies south of James River near its mouth, and extends from the river to the North Carolina line. The surface of the county is rather even, except for the abrupt descents to creeks and inlets in the northern part of the county, and for the scarp that separates the low ground, in which lies the Dismal Swamp, from the higher ground to the west. The principal stream is Nansemond River, a branch of James River. Jones Creek also flows into the James. Most of the southern part of the county drains to Blackwater River, while the south-eastern is included within the Dismal Swamp. Much of the surface is part of the Wicomico plain, at elevations between 60 and 90 feet. The abrupt scarp separating the Wicomico from a lower terrace extends from the North Carolina line northward past Suffolk and Chuckatuck. Lake Drummond,

part of which is in Nansemond County, has an elevation of 22 feet above sea level.

Geology.—Over nearly the whole county the Columbia sands and loams are the only beds that can be seen. North of Suffolk, along the banks of Nansemond River and its branches, the underlying dark greenish or bluish sandy clays of the Chesapeake, often filled with shells, are exposed in many places.

In the eastern portion of the county thick beds of mud and sand, which contain shell marl, have been cut by the canals leading to Lake Drummond. These beds, as shown by their fossils, are of Pleistocene age, and are included in the Columbia group.

Other formations, belonging to the Pamunkey, Upper Cretaceous, and Potomac groups, underlie the Chesapeake but are known only from the records of deep wells. The base of the Chesapeake is 350 to 500 feet below surface, and the base of the Pamunkey lies 450 to 600 feet deep.

UNDERGROUND WATERS.

Extent and distribution.—The water table throughout most of the southern and eastern parts of the county lies very near surface, and in wet weather many wells are full to overflowing. The supplies are generally soft, but because of the liability of pollution are not highly valued. In the northern and western parts of the county where the land lies higher, many wells near the edges of terraces are 30 feet deep or more. The supplies obtained are generally soft. Artesian waters underlie the whole county and attempts to get flows have been made at a number of places, but the only artesian wells in use in 1906 were at Suffolk and Everets. At the former place water is obtained from sandy beds high in the Upper Cretaceous; at the latter place from beds of sand and gravel near the top of the Chesapeake. The Upper Cretaceous water is soft and alkaline, the Chesapeake is less mineralized. Artesian water has been reported found near Chuckatuck, but no particulars as to quality are available.

Springs.—Springs are not especially abundant in Nansemond County, although there are some along the branches of James and Blackwater rivers. None of commercial importance has been reported. A spring of good flow, known as the Buckhorn, one-half mile north of Windsor, yields iron-bearing water.

Wells.—Though there are a considerable number of driven wells in the county, dug wells are far more plentiful. There were in 1906 not over 15

drilled wells in use. The dug wells are usually lined with wood, and, on wide, flat stretches where water is close to surface and surface drainage is defective, are not ideal sources of supply. The driven wells and nearly all the drilled wells are of small diameter. They are much preferable to the dug wells, and when conditions are favorable, that is, where the water lies in soft sand close to surface, driven wells with pitcher pumps attached cost but \$5 or \$6. The cost of drilled wells depends on their depth and diameter; 2-inch wells near Everets were sunk under contract for \$1 per foot to depths of 50 feet or more.

LOCAL SUPPLIES.

Suffolk is supplied with water from Lake Kilby, which in 1906 was distributed by the Portsmouth, Berkeley and Suffolk Water Co. A summary of the supply system is given on page 77.

Various manufacturing concerns use or have used water from dug wells. This is hard and of indifferent quality for boiler supply as it forms scale, and the use of a softening plant or of boiler compounds is necessary. Up to the time of the field work for this report attempts to get artesian water at Suffolk had, with one exception, been failures. This was not because artesian water can not be had but because the wells did not go deep enough. There is a great thickness, probably not less than 300 feet, of Chesapeake sandy clay underlying Suffolk, in which there seem to be no beds that yield water freely. The successful well, that of the Norfolk & Portsmouth Traction Co., is reported to be 803 feet deep. Possibly it might have obtained water enough at a higher level, but the drillers were seeking a flow (an impossible undertaking as the elevation of the well is 63 feet), and continued drilling. The yield is small and the well has given more or less trouble ever since its completion. Apparently the water-bearing sand is fine. The water rises to 33 feet of surface and a deep well pump obtains 11 gallons per minute. The water is said to work well in a boiler if not allowed to become too concentrated, and to be good for ice-making.

The following analysis shows its softness, low lime content, and alkalinity; the chief substance in solution undoubtedly is bicarbonate of soda.

*Analysis of water from deep well of Norfolk & Portsmouth Traction Co.,
Suffolk.*

(First Scientific Station for the Art of Brewing, analyst.)

	Parts per 1,000,000
Total residue	596.0
Loss by calcination	20.0
Residue after calcination	576.0
Iron (Fe)	large traces
Lime (CaO)	4.0
Magnesia (MgO)	2.9
Carbonate of soda (Na_2CO_3)	493.0
Chlorine (Cl)	23.0
Nitrate radicle (NO_3)	0.0
Nitrite radicle (NO_2)	0.0
Free ammonia	0.0
Albumenoid ammonia	0.0
Oxygen required	0.02
Total hardness	128.0

Deep wells north of Suffolk.—A group of artesian wells has been sunk near Everets, on Everets Creek. Some are just at the foot of the Wicomico scarp and their heads, as they are of shallow depth, little over 50 feet, are due to the level of the water in the Wicomico plain to the west. In 1906, there were about 8 of these wells, the deepest being down 110 feet. The heads range from 4 to 10 feet above the creek, which is tidal. The following record of one of the wells shows the general character of the beds overlying the water-bearing sand:

Record of well of T. J. Saunders, Everets.

(Authority, T. J. Saunders, owner.)

Material	Thickness (Feet)	Depth (Feet)
Clayey soil on marl	8	8
Blue marl, with few shells	16	24
Black sand, with hard layers or "rocks"	2	26
Blue sand, lighter colored at base	28	54
White sand	30	84

Efforts to find the same flow farther southeast have not been successful; the water-bearing sand probably thins out or becomes clayey, though as the sand dips to the east it is barely possible that the wells did not go

deep enough. At Reids Ferry, on Everets Creek, 5 miles southeast of Everets, a 150-foot well sunk for the Nansemond River Brick and Tile Co. did not find water, nor did a well 188 feet deep, a mile east of Chuckatuck, which when the driller stopped work was in black and white sand. A later and deeper well east of Chuckatuck is reported to have found a flow. The general character of the flows at Everets is shown by the field assay in table 7b.

Shallow well conditions near various villages in the county are summarized in the following table, most of the data being obtained from postmasters.

Details of dug wells in Nansemond County.

Location	Depth of well (Feet)	Water bed	Quality of water
Cleapur	16-90	Shallow, sand; deep, clay.	Shallow, soft; deep, hard.
Copeland	10-25	Sand	Soft
Hobson	16	Blue mud	Soft
Holland	10-34	Sand	Soft
Savage Crossing	8-30	Shallow, sand; deep, blue marl and "black dirt."	Shallow, poor; deep, good.
Valeria	6-10	Shallow, sand; deep, clay.	Shallow, poor; deep, good.

Conclusions.—There is undoubtedly plenty of artesian water under Nansemond County, but conditions are not so favorable for free flows of good water as in counties to the west. The upper Chesapeake sands are patchy and their limits can be determined only by drilling. The sands lower in the Chesapeake, and those in the Pamunkey, are uncertain water-bearers, but may yield flows with heads of 30 feet above tide through wells carefully drilled and screened. The quality of all the artesian waters deteriorates toward the east and near James River, and in the northeast corner of the county the deep flows may be too mineralized for domestic or industrial purposes.

NEW KENT COUNTY.

General description.—New Kent County, formed in 1654 from York County, lies between Chickahominy and Pamunkey rivers.

The topography is much like that of Charles City County. The highest of the terraces, the Sunderland, has an undulating surface sharply cut by stream valleys. Its greatest elevation is 140 feet. The Wicomico plain is developed along Pamunkey River, as is the lower Talbot, the latter com-

prising much of the land embraced in the wide meanders of the river. Both Chickahominy and Pamunkey rivers have few tributaries rising in the county; the largest of these, Diascond Creek, empties into the Chickahominy and forms part of the eastern boundary of the county. The divide between Chickahominy and Pamunkey waters crosses the northern part of the county, New Kent Courthouse being on it.

Geology.—Columbia loams mantle the surface. On neither Chickahominy nor Pamunkey rivers are Pamunkey (Eocene) beds exposed, the highest formation visible below being the St. Mary's formation of the Chesapeake (Miocene) group. Its dark, greenish sandy clays are exposed along stream gullies and in bluffs on the south side of Pamunkey and York rivers. The base of the Calvert formation of the Chesapeake group lies above tide level along the western boundary of the county and 180 feet below at Plumpoint. The base of the Pamunkey lies possibly 200 feet below tide water in the western side of the county, and 350 feet below in the east. Whether Upper Cretaceous (Matawan) beds extend as far west as the eastern side of the county is doubtful. Unquestionably, there is a considerable thickness, possibly over 600 feet of Potomac (Lower Cretaceous) beds above bed rock.

UNDERGROUND WATERS.

Distribution and quality.—New Kent County is well watered. Numerous rills and creeks are fed by springs. The ground water in the sands of the Columbia formations is generally abundant and soft. The artesian sands in the Pamunkey group carry plenty of soft water that gives flows up to 26 feet above tide. The Calvert sands at the base of the Chesapeake yield light flows in the eastern part of the county, and, if reports are to be trusted, in the Chickahominy valley as far west as Roxbury. Little is known of the Potomac waters, but they are undoubtedly abundant and generally good.

Springs.—There are many springs in the county, some of which have attracted notice by reason of their size or the quality of their waters. A few are used for domestic supply and one or two are thought to have medicinal value. A spring, or shallow well, 3 miles north of Talleyville, flows about 1 gallon per minute of water that has been sold as Belmont Lithia water. The water comes from marl, and the chief substance in solution is bicarbonate of lime. The appended analysis, furnished by the proprietor, R. E. Richardson of Talleyville, has been recalculated to parts per, 1,000,000.

Analysis of Belmont Lithia water.

(W. H. Taylor, analyst.)

	Parts per 1,000,000
Total solids	221.
Calcium bicarbonate ($\text{CaH}_2(\text{CO}_3)_2$)	135.
Ferrous bicarbonate ($\text{FeH}_2(\text{CO}_3)_2$)	15.
Magnesium bicarbonate ($\text{MgH}_2(\text{CO}_3)_2$)	11.
Manganese bicarbonate ($\text{MnH}_2(\text{CO}_3)_2$)	0.5
Sodium bicarbonate (NaHCO_3)	15.
Lithium bicarbonate (LiHCO_3)	0.1
Sodium chloride (NaCl)	3.4
Potassium chloride (KCl)	1.2
Ammonium chloride (NH_4Cl)	trace
Potassium sulphate (K_2SO_4)	6.3
Calcium phosphate ($\text{Ca}_3(\text{PO}_4)_2$)	0.6
Calcium nitrate ($\text{Ca}(\text{NO}_3)_2$)	trace
Alumina (Al_2O_3)	0.1
Silica (SiO_2)	33.
Sulphuretted hydrogen (H_2S) 0.88 cubic inches per imperial gallon.	

Wells.—Dug wells, usually cased with wood, are practically the sole source of water supply on the higher terraces. On the lower terraces are some driven wells. The drilled wells are practically confined to the low ground along Pamunkey and Chickahominy rivers. Nearly all are of small diameter; the depths reported range from 150 to 260 feet.

LOCAL SUPPLIES.

More wells have been driven at Plumpoint than at any other place in the county. They all draw on the Calvert, basal Chesapeake, sands reached by the 165-foot wells at West Point, and yield water of the same quality. Heads are about 20 feet above mean high tide. Above Plumpoint at Whitehouse possibly 10 wells have been driven, all of which draw on the same beds, basal Pamunkey, as the wells at Lester Manor in King William County. The heads range up to 35 feet above mean high tide. The flows, where proper care has been taken in casing, equal the average of Pamunkey wells of equal diameter, being about 5 gallons per minute.

The following generalized record of a well at Whitehouse was published by Darton:^a

^aDarton, N. H., *Op. cit.*, p. 174.

Record of well at Whitehouse.

(Authority, P. H. Sweet, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil	15	15
Yellow clay	10	25
Blue fullers earth	40	65
Several thin rock strata, one 18 inches thick.....	5	70
Soft sand rock	25	95
Red clay	20	115
Greensand marl (?)	50	165
Black sand; water at 210 feet.....	45	210

Along Chickahominy River wells have been sunk at Providence Forge and near Windsor Shades (Boulevard P. O.). No records were kept of any of these wells, but all obtain water from practically the same horizon in the Pamunkey. At Providence Forge several wells have been drilled; one owned by Col. E. B. Townsend is 216 feet deep, and flows 10 gallons per minute at an elevation of 20 feet above sea level. A field assay of the water is given in table 9. Another well, that of R. E. Richardson, is 215 feet deep; it flowed at first but later had to be pumped. The loss of flow is explained by insufficient casing.

The well at Boulevard is probably the finest in the county. It is 260 feet deep, 4½ inches in diameter, and flows 52 gallons per minute at an elevation of 22 feet above mean high tide. This large flow is probably due not so much to the diameter of the well as to the character of the water bed, which, according to report, was a gravelly sand, whereas at Providence Forge the water bed is finer textured. An analysis of the water from the well at Boulevard appears in table 9. The water is noteworthy for the small proportion of mineral matter it contains.

For the supply of temporary saw-mills dug wells are used. In 1906, there were possibly a dozen such mills in the county, obtaining water from wells 25 to 50 feet deep. Information regarding dug wells at a number of villages is given in the following summary:

Details of dug wells in New Kent County.

Location	Depth of well (Feet)	Water bed	Quality of water
Barhamville	12-30	Loam and marl	Shallow, soft; deep, slightly hard.
Dash	18-60	Iron crusts, sand	Hard
Oak	20-60	Shallow, loam; deep, clay.	Soft
Plumpoint	10-15	Sand and gravel	Hard
Providence Forge	10-50	Shallow, loam; deep, marl	Shallow, fair; deep, good.
Funstall	10-20	Shallow, clay; deep, marl.	Soft and hard

Conclusions.—To properly cased wells the Pamunkey sands will furnish supplies far in excess of present draughts. The Potomac group undoubtedly contains numerous sands that will yield ample flows with heads of 30 feet or more, and recourse can be had to them in case the head of the Pamunkey waters at any place is lowered by the interference of wells drilled too closely or allowed to flow without restraint.

NORFOLK COUNTY.

General description.—Norfolk County, formed in 1697 from Lower Norfolk, extends from the mouth of James River southward to the North Carolina line. In or near Norfolk are many large manufacturing establishments and no less than five railroads have terminals on Elizabeth River.

Almost all the surface of the county forms part of the Talbot terrace, which has a maximum elevation of about 25 feet, hence there are wide expanses of practically level ground and considerable swamp land. Most of the swamp is in the southwestern part of the county, and is part of the great Dismal Swamp of Virginia and North Carolina. The surface of this swamp slopes slightly to the northeast and southeast from the foot of the Wicomico-Talbot scarp which forms its western boundary. Lake Drummond, the only considerable body of fresh water in the State of Virginia, is near the center of this swamp. Its surface is 22 feet above tide level. The principal streams, Elizabeth River and North River, are shallow inlets which head in marshy creeks; Elizabeth River empties into James River and North River into Currituck Sound.

Geology.—The vari-colored loams of the Talbot formation are exposed here and there in shallow road cuts, and except for swamps or marshy tracts and strips of dune sand the Talbot loams form the soils. Below lie soft blue clays and bluish sands containing here and there beds of marine shells of Pleistocene age. The Talbot varies in thickness from 5 feet to perhaps 75 feet; it can not, by available well records, be sharply differentiated from the topmost beds of the Chesapeake group (Miocene). The maximum thickness of the Chesapeake group is not less than 600 feet. The topmost formation of the Chesapeake contains water-bearing beds which have been found by driven or drilled wells of moderate depth. The lower formations of the Chesapeake seem to have few beds coarse enough to convey water readily. The relations of the Chesapeake to the underlying Pamunkey, and the evidence of the deep wells, are discussed elsewhere (see page 97 et seq.).

UNDERGROUND WATERS.

Distribution and quality.—The chief sources of domestic water supply in Norfolk County are the gravels and sands in the Talbot formation, from 5 to 50 feet below surface. The water from the shallow beds at most places is soft, but at many is iron-bearing; and at some, near bodies of salt water, is brackish. The deeper beds give hard water which in some places is iron bearing. The discontinuous sand beds in the upper portion of the Chesapeake yield supplies that are, as a rule, iron-bearing and hard, in fact too highly mineralized for general domestic use.

Springs.—There are in Norfolk County comparatively few springs, but three have been developed on a commercial scale. Two, the White Oak and Landale, front inlets from Mason's Creek, 5 to 5½ miles north of Norfolk. They yield soft, clear water from the Talbot sands. The output has been sold in Norfolk. At the Landale Spring the water issues from the sands just above tide level, and comes from some distance below the surface. The flow varies slightly with stages of the tide. The spring is some distance from the nearest house and the sanitary conditions, when the spring was inspected, were excellent. The following analysis, recalculated to express results in standard form, was furnished by the owner, W. J. Land.

Analysis of Landale Mineral Spring water.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	87.
Silica (SiO ₂)	5.3
Iron (Fe)	0.06
Aluminum (Al)	0.18
Calcium (Ca)	5.8
Magnesium (Mg)	2.5
Sodium (Na)	14.
Potassium (K)	1.3
Lithium (Li)	0.01
Iodine (I)	0.009
Bromine (Br)	trace
Manganese (Mn)	trace
Arsenic (As)	trace
Bicarbonate radicle (HCO ₃)	9.2
Sulphate radicle (SO ₄)	28.
Nitrate radicle (NO ₃)	5.5
Chlorine (Cl)	13.

The White Oak Spring is situated near the Landale, and the water probably comes from the same horizon. The following analysis, which has been recalculated, was furnished by the company putting the water on the market.

Analysis of White Oak Mineral water.

(W. H. Taylor, analyst.)

	Parts per 1,000,000
Silica (SiO ₂)	5.4
Iron (Fe)	trace
Calcium (Ca)	21.0
Magnesium (Mg)	2.8
Sodium (Na)	14.0
Potassium (K)	3.6
Bicarbonate radicle (HCO ₃)	55.0
Sulphate radicle (SO ₄)	29.0
Chlorine (Cl)	15.0

Another spring, owned by Joseph Freitas, on Mason's Creek about 1½ miles due west of the two springs mentioned, has shipped water from time to time.

Wells.—There are probably more driven wells in Norfolk County than in any other county in Virginia. Most of them are shallow, going to the first water-bearing sand. There are many dug wells, most of which are not over 15 feet deep, and a few drilled wells. In some places cisterns are used. The more important deep wells have been mentioned on pages 97 to 116.

LOCAL SUPPLIES.

The city of Norfolk is supplied with water by three distributing systems owned by the city, the Norfolk County Water Co., and the Portsmouth, Berkeley & Suffolk Co. The size, capacity, and general equipment of the different supply system are described on pages 75-81.

In the outskirts of the city are many driven wells. G. B. Todd of Norfolk, who has driven a large number, states that east of Elizabeth River in Norfolk County are two water beds; one at 10 to 15 feet, yields water that is generally soft but is irony in places; and the second at 35 to 100 feet, yields water that is generally harder and is irony at a few places. The following records, furnished by Mr. Todd, show the character of the Talbot beds of the Columbia group.

Record of test-boring, corner of Brooke Avenue and Brush Street, Norfolk.

Material	Thickness (Feet)	Depth (Feet)
Made ground	4	4
Moist sand	3½	7½
Mud with some sand	7	14½
Mud	6½	21
Yellow clay and mud	7	28
Soft mud	8	36
Fine sand	2	38

This well was driven on made ground, formerly a marsh.

Record of test-boring on Reeves Avenue at river bank, Norfolk.

Material	Thickness (Feet)	Depth (Feet)
Made ground	3½	3½
Gray sand, water-bearing	8½	12
Yellow sand, almost dry	11	23
Blackish mud, very soft, mixed with fine sand.....	17	40
Solid coarse sand, water-bearing		40

At Lambert Point, a suburb which in 1906 had a separate government, Norfolk County water is used by nine-tenths of the inhabitants. There are, however, numerous cisterns and some driven wells. The latter find two sources of supply; the first water, at 10 to 12 feet, is called poor; deeper water, at 45 feet, is hard, and in places too iron-bearing for domestic use. The Norfolk & Western Railway Co. has used Norfolk County water largely at its yards and terminal on the Point. It once procured water from a system of driven wells 2 miles east of the Point, and subsequently tried a shallow well 30 feet in diameter about a half mile east of its yards. The water from the deep well, mentioned on page 107, is too highly mineralized for boiler use.

At Sewell Point, the site of the Jamestown Exposition, water can be obtained almost anywhere by driving a pipe down 8 or 10 feet. This water is not considered good. The Exposition grounds were supplied by the Norfolk County Co. At Ocean View and on Willoughby Spit, where there are many suburban residences and summer cottages, water is obtained from driven wells. On the Spit the wells are 20 to 25 feet deep. The water is apt to be irony. At Ocean View station wells are about 12 feet deep, and yield better water than along the beach, where they average 18 to 20 feet and yield irony water. A few wells, from 20 to 30 feet deep, strike water in a blue sand below a blue mud. The water has a slight sulphur taste and at some wells is irony. A driller reports that in the vicinity of Ocean View a bed of shells is occasionally struck in the blue sand above the blue mud at a depth of 8 feet. This shell bed is probably of Pleistocene age and part of the Columbia group.

Darton^a has published records of several borings made by the city of Norfolk in search of shallow water east of the city. The two following are given in slightly modified forms to show the general character of the Columbia materials, and the depth to the main water beds.

^aDarton, N. H., Norfolk folio, U. S. Geol. Survey, 1902, p. 4.

Poorhouse tract swamp.

Material	Thickness (Feet)	Depth (Feet)
Muck	4	5
Firesand	4	9
Sand and clay	23 $\frac{2}{3}$	32 $\frac{2}{3}$
Blue clay	1 $\frac{1}{2}$	35 $\frac{1}{6}$
Sandy clay	3 $\frac{1}{4}$	38 5-12
Sand and clay	7 $\frac{1}{2}$	45 $\frac{1}{2}$
Gravel, with water, on sand	6 $\frac{1}{8}$	51 $\frac{5}{8}$

Drummond woods.

Material	Thickness (Feet)	Depth (Feet)
Sand	3	4
White sand	9	13
Sand and clay	8	21
Clay and sandy clay	9 $\frac{1}{2}$	30 $\frac{1}{2}$
Sandy clay	5 $\frac{2}{3}$	36 $\frac{1}{6}$
White sand	2 $\frac{1}{6}$	38 $\frac{1}{3}$
Gravel, with water, on sand	5 $\frac{2}{3}$	44

South of Norfolk, along the South Branch of Elizabeth River, wells have been put down for the boiler supply of mills. Most yield fair water. The E. S. Barnes Co., at its plant on the east bank of the South Branch, 2 miles above the Norfolk Navy Yard, has 10 wells 72 to 86 feet deep. A partial analysis by the Hartford Steam Boiler Co. showed 648 parts of solid matter per 1,000,000, considerable soda, lime, magnesia, chlorides, and sulphates, some silica and potash, and a little iron; the chief substance in solution was sodium chloride, with "traces" of calcium and magnesium sulphates, a rather poor boiler water. Another well, 120 feet deep, yielded somewhat similar water, containing 652 parts of solid matter per 1,000,000. A group of 14 wells, 15 feet deep, at the same plant, yielded water that contained only 164 parts of solid matter per 1,000,000, a good boiler water. In this water the hardness was chiefly temporary, from carbonates of lime and magnesia.

The Pocomoke Guano Co. obtains water from a well 86 feet deep, near Elizabeth River. The following record was furnished by the company:

Record of 86-foot well of the Pocomoke Guano Co., near Elizabeth River.

Material	Thickness (Feet)	Depth (Feet)
Hard black dirt	3	3
Soft fresh mud, swamp muck	9	12
Blue marl and mud	68	80
Shells, sand and gravel, water-bearing		80

A partial analysis of the water from this well (table 7) shows an unusually high percentage of organic matter.

Another well, that of the Roanoke Railroad & Lumber Co., not far from the two plants previously mentioned, penetrated the following beds, according to the company.

Record of well of Roanoke Railroad & Lumber Co.

Material	Thickness (Feet)	Depth (Feet)
Surface soil and sand	15	15
Clay, sands at base, water	10	25
Black mud with fine shells, clear water at about 53 feet.....	28	53
Black mud	10	63

The water is said to be slightly salty and to scale badly in a boiler.

The pumping plant of the Portsmouth, Berkeley & Suffolk Water Co. draws on some 35 6-inch wells, 25 feet deep, about 3 miles south of Berkeley. The wells obtain water from a bed of gray sand below blue mud. The water level of the wells varies considerably. At times it is within 3 feet of surface, but under heavy pumping falls to 17 feet. In 1906, there were no buildings on the tract and the possibility of pollution was remote. The water is said to be slightly hard. A partial analysis furnished by the American Waterworks & Guarantee Co. of Pittsburg, Pa., given in table 7, shows a chlorine content of 17 parts per 1,000,000, about the average in Norfolk County for unpolluted shallow waters at points away from salt creeks or arms of Chesapeake Bay.

At Oaklet, southeast of Norfolk, two water-bearing sands are tapped by the driven wells: The first, 12 to 18 feet below the surface and 8 to 10 feet thick; the second, about 40 feet below the surface, and separated from the first by blue clay. A well driven 124 feet proved a failure, finding no water at that depth. The water from the 40-foot sand is considered more healthful than that from the 15-foot.

The city of Portsmouth is supplied with water from Lake Kilby by the Portsmouth, Berkeley & Suffolk Co. Probably nine-tenths of the inhabitants of Portsmouth use this water, the remainder using driven wells and cisterns.

At the Scottsville yards of the Seaboard Air Line Railway, 1½ miles west of Portsmouth post-office, there are 14 2½-inch wells and 12 4-inch wells, all 60 to 64 feet deep. The elevation of the ground at the wells is about 10 feet. The following record was furnished by the company:

Record of driven wells at yard of Seaboard Air Line Railway, Portsmouth.

Material	Thickness (Feet)	Depth (Feet)
Fine gray sand	4	4
Very fine gray quicksand with bits of rotten wood and tree trunks at 18 to 20 feet.....	31	35
Bluish-gray clay from 8 to 10 feet thick.....	9	44
Very fine light buff sand, water-bearing	6	50
Hard, coarse gravel	10	60

No shell beds were found. The wells have double points, and are driven into the gravel because points in the soft sand corrode quickly. The yields are comparatively free, though the 2½-inch wells are sometimes choked by sand. The draught in 1906 was 200,000 gallons of water daily, which was used for locomotive supply and general purposes. It is considered a good boiler water. Analyses of water from the old and new wells are given in table 7.

The old wells comprise 14 2½-inch and 2 4-inch wells, nearer the creek than the new wells (10 4-inch), and the water consequently contains more sodium chloride. Pumping for several months had slight effect on the quality, as is shown by the analyses.

At Port Norfolk, the Norfolk & Portsmouth Traction Co. has, at a power plant at the corner of Mount Vernon Street and Florida Avenue, a mile south of Elizabeth River, 24 wells, 22 of which are 1½ inch in diameter and 16 feet deep, and two are 2 inches in diameter and 50 feet deep. In 1906, these supplied all the water for the boilers, rated at 950 horsepower, also for washing cars and for fire protection, in all about 55,000 gallons daily. The water is stated to work well in a boiler, forming but little scale. The water from the deep well is said to be harder than that from the shallow wells. A partial analysis furnished by the company, recomputed to standard form, is given in table 7.

Near the Norfolk & Portsmouth Co.'s power house the Air Line Manufacturing Co. had, in 1906, 5 1½-inch wells 38 to 40 feet deep, which supplied water for a boiler capacity of 160 horsepower. The following record is reported:

Record of wells of Air Line Manufacturing Co., Port Norfolk.

Material	Thickness (Feet)	Depth (Feet)
Clay and sand with water at 8 to 14 feet.....	14	14
Blue mud	20	34
Sand, water-bearing	4	38

The water was considered hard and a boiler compound was used to prevent scale. A partial analysis, recomputed, is given in table 7.

At the U. S. Naval Hospital in the southern part of the city 4 driven wells, 2½ inches in diameter and 35 feet deep, were sunk 400 feet back from Elizabeth River. The maximum yield obtained by pumping was 50 gallons per minute. The water, which rises to 8 feet of surface, or about tide level, is rather hard and is not used in boilers at the hospital. A partial analysis, furnished by the medical inspector in command, is given in table 7. In the same table appears an analysis of water from a shallow well owned by the Portsmouth Knitting Mills.

In the rural sections of Norfolk County, driven as well as dug wells generally go only to the first water-bearing sand, but some driven wells are 40 to 80 feet deep. The quality of the water varies from place to place, but, except close to tidal inlets, is usually soft. Near the Dismal Swamp, where the water table is almost at the surface, the water is apt to be highly colored and of poor quality.

Data collected regarding shallow wells at a number of places are summarized below:

Details of shallow wells in Norfolk County.

Locality	Depth of well (Feet).	Water bed	Quality of water
Cornland	8-45	Sand	Deep, good
Deep Creek	6-12	Sand	Good
Fentress	10-30	Sand	Shallow, soft, or salty; deep, irony
Gilmerton	8-10	.....	Bad
Grassfield	8-14	Sand	Poor to good
Great Bridge	10-15	Sand	Hard
Hickory	10-30	Sand	Soft to hard
Indian Creek	8-12	.....	.....
Link	8-18	.....	Shallow, soft; deep, hard.
Oaklet	12-18	Sand	Shallow, poor; deep, good
Piney Beach	10-15	Clay, sand and gravel.	Brackish
Port Norfolk	10-35	Marl	Not good
Pughs	25-30	Sand	Soft
Sewell's Point	10-50	Sand	Soft, irony, hard
Tanners Creek	10-12	Sand	Soft
West Norfolk	20-30	Sand	Hard

At some places where the shallow water is poor, cisterns are more or less used.

At Great Bridge a dug well struck a shell bed containing "large oyster shells" at 20 feet. Water was found at about 30 feet which quickly filled the well. The owner uses the water for irrigation, and reports pumping 214 gallons per minute without lowering its level.

Conclusions.—Ground water suitable for household and domestic use can be had at many places in Norfolk County at slight cost. Because of the easy pollution of dug wells, unless protected with more than average care, driven wells are to be preferred; water from 25 to 50 feet is less liable to pollution than that from 5 to 20 feet below surface. The best water will be found on dry tracts 10 to 30 feet above sea level, the poorest on lower ground along tidal inlets. Deep artesian water can be had under the whole county; its quality is problematical. Flows of such clear, soft water as are found in counties to the west are not to be expected.

NORTHAMPTON COUNTY.

General description.—Northampton County covers the southern part of the peninsula known as the Eastern Shore. The topographic aspects of the county are much like those of Accomac. Low islands or barrier beaches fringe the eastern coast; behind these are broad, shallow lagoons, mud flats bare at low tide, and wide stretches of salt marsh. On the bay side the shoreline is sharper. The surface elevations apparently lie below 35 feet and the surface is included in the lower Columbia terraces.

Geology.—Reddish buff to yellow clay loam underlies the sandy soil, and is underlain in turn by white and yellowish sands with occasional beds of light clay. The maximum thickness of these beds may be 40 feet. Beneath are the same series of silver-gray or bluish-gray sands, shell beds, and soft, dark clays, that are found in Accomac County, and are regarded as part of the Columbia group. Fewer drilled wells have been sunk in Northampton than in Accomac County, hence information regarding beds of fossil shells is scant, but they evidently occur at varying depths, the least depth reported being 30 feet, near Brighton. There is no evidence available for sharply separating the bottom of the Columbia (Pleistocene) from the top of the Chesapeake (Miocene), but the Columbia may be 100 feet thick. Pliocene beds may be present but have not been recognized.

UNDERGROUND WATERS.

Distribution and quality.—Good water has been found at most places. The depth to the water table, the "first spring," may be 20 feet in places, but usually is decidedly less and probably averages not far from 10 feet. The water table after prolonged wet weather comes to the surface on many flat stretches of land. The water from the deeper sands, the "second and third springs," contains, as a rule, more lime and less iron than that from the "first spring," and, if proper care is taken in its recovery, is practically above suspicion of pollution from surface sources.

Springs.—There are very few springs in the county. One 6 miles east of Chesapeake is reported to flow 1 gallon of clear, soft water per minute.

Wells.—The dug well is still the most widely used source of water supply. Wood casing is being supplanted by tile. Driven wells are becoming more and more popular. It is claimed by some persons that since driven wells came into general use there has been a marked improvement in the public health.

Most of the driven wells get water from the "first spring" and are not over 20 feet deep, but may go down 50 or 60 feet, and some drilled wells go to depths of 100 feet and more. The usual charge for "driving pumps" (putting down 1¼-inch driven wells), is about 30 cents per foot, the point and pump being priced separately. The type of point most used is 3 feet long with 60-mesh gauze screens; gauze as fine as 90-mesh being rarely used.

Wells of 1¼-inch diameter are almost invariably driven. Sometimes the pipe strikes "rocks" so dense that a 75-pound hammer falling 15 feet will not start it, but where conditions are favorable 125 feet of pipe can be driven in 1½ days. Drilled 2-inch wells are put down by the wash process, charges varying from 50 cents to \$1 per foot, with point and pump included. These wells often have 6-foot Cook strainers.

LOCAL SUPPLIES.

At Exmore supplies are obtained from the "first spring," wells averaging 10 to 20 feet deep. The tank of the New York, Philadelphia & Norfolk Railroad is supplied with water from a 14-foot dug well, 18 feet in diameter, supplemented by points driven to the "second spring" at 30 to 40 feet. A partial analysis of the water from the 14-foot, 30-foot, and 40-foot wells is given in table 7. The analyses are chiefly interesting for the increase in hardness and in chlorine with depth. An analysis of water from a 12-foot well, made by C. B. Dudley for the Pennsylvania System, showed 8.4 grains of total solid residue per gallon, consisting principally of lime and magnesia sulphate with no carbonate, a slightly corrosive water.

The water in most of the village wells is soft and contains little iron. The pumps and dug wells at Nassawadox and Franktown show wide variations in supplies. At Nassawadox, drillers know 4 "springs" at depths of 8, 18, 28, and 38 feet. Water from the first is considered fairly good, that from the second and third irony, while that from the fourth has a decided sulphur odor. At Franktown, pumps are driven to two water beds, at 20 and at 35 to 40 feet. Both furnish soft water that is not irony, but local physicians prefer water from the deeper bed.

At Eastville, water is found at approximate depths of 10, 30, and 40 feet. Most driven wells go to the 30-foot bed which yields a soft, slightly iron-bearing water. One well driven 105 feet found no water below 33 feet. A well at the Courthouse, much used by the public, is driven 40 feet, and yields good water. (For field assay, see table 7.) The tank of the New York, Philadelphia & Norfolk Railroad has been supplied from a 14-foot dug well that gives a satisfactory boiler water. A partial analysis appears in table 7. Another analysis made by C. B. Dudley showed 11.01 grains per gallon of total solid residue, consisting chiefly of lime and magnesia sulphates, with considerable chlorides.

At Cheriton most pumps get water at 16 or 30 feet; it is said to be medium soft and is more or less iron-bearing, though at some wells it contains very little iron. Water having a decided sulphur odor was found at 63 feet in a well at Huff Brothers' store, and is no longer used. The record of this well is as follows:

Record of well at Cheriton.

(Authority, Huff Brothers, owners.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Yellow and gray sand, with water at 14 to 16 feet and 29 to 30 feet	29	30
Blue marsh mud	32	62
Sand and shells: sulphur water	1	63

There are many flowing wells in the county but not nearly so many as in Accomac. Most of them are on the ocean side, several being on Upshur Neck. One of these, on Brownsville Creek, driven by W. M. E. Tilghman, of Nassawadox, for Thomas Upshur, is 127 feet deep, 1 $\frac{1}{4}$ inches in diameter, and flowed 1 $\frac{1}{2}$ gallons per minute at an elevation of 5 $\frac{1}{2}$ feet above mean high tide. At Oyster, 5 1 $\frac{1}{2}$ -inch wells were drilled some years ago for W. T. Travis. They are said to range in depth from 175 to 225 feet and to strike silver gray sands containing marine shells. The flows are about 1 gallon per minute at 3 feet above mean high water, and about one-third more at high tide than at low. The water has a faint sulphur odor but is excellent and is used for domestic supply and on fishermen's boats. A field assay of water from one well is in table 7.

Cape Charles is the only town in Northampton County having a public supply system. The supply in 1906 came from an open well, 20 feet in diameter and 20 feet deep, and 17 3-inch points, 3 driven to 40 feet, and

14 to less depths. Twelve of these points were owned by the city and 5 by an ice plant. Owing to the steady draught the water table, normally about 8 feet below surface, has been lowered over a considerable area about the points, so that the 12-foot well is ordinarily entirely dry, and contains a few inches of water only after prolonged wet weather. The water from the points which tap the "second spring" in the Talbot sands makes good ice, but forms scale in boilers. In 1906, about three-fourths of the town's population used city water, the remainder using pumps driven to the "first spring."

At the shops of the New York, Philadelphia & Norfolk Railroad are 22 40-foot points and 4 90-foot points directly connected to a steam pump. The log of the deeper wells, situated at 4 feet above mean high tide, is as follows:

Record of well of New York, Philadelphia & Norfolk Railroad, at shops, Cape Charles.

(Authority, Geo. Russell, superintendent motive power, N. Y. P. & N. R. R.)

Material	Thickness (Feet)	Depth (Feet)
Surface soil	1	1
Buff sandy clay	4	5
Yellow sand, water at 10 feet.....	10	15
White sand, quicksand with water	25	40
Gravel and pebbles, pebbles yellow, white, red, and black....	3	43
Pea-green marl, no shells	10	53
Black mud with rotten wood, no shells	17	70
Shells and sand: good water at 90 feet which rises to 6 feet of surface	25	95

An attempt to get a flow by drilling deeper, made some 20 years ago, proved a failure, no freely water-bearing beds being found to a depth of 300 feet, but the character of the rig used prevented this test from being decisive. In 1910, the railroad had a well sunk over 1,500 feet by a careful driller, but found no strongly water-bearing sand between 40 and 1,520 feet.

The water from the driven wells is used in stationary boilers, also by locomotives and steamboats. It forms a hard scale. At the shops the boilers are run in weekly alternation and thoroughly cleaned when idle. Soda ash caused priming and various boiler compounds tried were too costly for the results obtained. Analyses of water from a 14-foot dug well and from a 90-foot point are given in table 7. It is not impossible, in view of the depression of the water table by pumping and the situation of the wells near the bay, that salt water may gradually work inland and impair the quality of the present supplies at the shops.

The conditions governing the underground occurrence of fresh water on the low islands along the coast have already been discussed (page 117). To get water other than rain water is a matter of considerable importance because of the growing popularity of the islands as resorts. Water from shallow driven pumps is the most available, though this is as a rule high-colored, irony, and, after high tides or dry weather, brackish. Wells sunk 100 to 250 feet may give better supplies, much depending on the location of the island with reference to catchment areas on the mainland.

The conditions on several of these islands are summarized below:

Details of wells on islands of Northampton County.

Island	Deepest well (Feet)	Level of water above or below surface (Feet)	Yield (Gal. p. m.)	Quality	Use
Bone	169	9	3	Irony	Domestic
Mockhorn	185	-1½	.....	.....	Domestic and stock
Fisherman's	14	.....	.....	.....	Abandoned
Sandy, or Cherry- stone.	169 (?)	+1½	10	Slightly saline	Boiler

No records of the materials passed through have been kept, but water-bearing sands of the Columbia group (Pleistocene) supply the shallow wells, and Chesapeake (Miocene) sands the deep wells.

The well on Sandy Island is of interest on account of the small area and slight elevation (less than 5 feet) of the island, which is nearly covered by a large fish factory. The well supplies 20,000 gallons per day, the flow at 1¼ feet above tide varies from nothing to 10 gallons per minute, but, by pumping, 80 gallons per minute can be obtained. The water, though brackish, is used for drinking and cooking and to supply 7 tubular boilers, rated capacity 800 horsepower. Three fishing steamers owned by the company also use the water. It forms a hard, white scale. A field assay is given in table 8.

The wells on Fisherman's Island were driven to supply the Quarantine Station, the points became clogged by rust, and the wells were abandoned. The Bone Island well was sunk for a club-house and other buildings. The water is used for drinking and other purposes, but contains a rather large percentage of chlorine and is high in iron.

Data regarding wells at other places in the county are summarized below:

Details of wells in Northampton County.

Location	Depth of well (Feet)	Water bed	Quality of water
Birdsnest	8-30	Sand	.....
Capeville	14-18	Sand	Shallow, fair; deep, good.
Chesapeake	10-60 driven and drilled 12-30 dug	.....	Shallow, fair, deep, good.
Dalleye	12-50 driven 10-15 dug	.....	Shallow, salty; deep, better.
Eastville	12-15 dug 20-35 driven	Shallow, sand, deep, sand and gravel.	Good
Franktown	10-60	.....	Good
Mashipongo	12-18	Sand	Fair to good
Reed's Wharf	4-25	Sand	Poor to fair
Stewart's Wharf	6-30	Sand	Salty to good
Wardtown	10-20	.....	Poor to fair
Willis' Wharf	8-25	.....	Shallow, soft; deep, hard.

Conclusions.—At most points in the county driven wells, 30 to 50 feet deep, are preferable for sanitary reasons to those 10 to 20 feet deep; and for the same reason driven wells are much preferable to dug wells. Artesian waters that will rise 3 to 5 feet above tide level can be had by wells 75 to 100 feet at many places, but the sands are not continuous, and depths to flows can not be predicted if no drilling has been done in the vicinity.

While the lower formations of the Chesapeake group (Miocene) and the sands of the Pamunkey group (Eocene) may contain beds that will give flows at elevations less than 10 feet, and while the Upper Cretaceous and the Potomac undoubtedly contain such beds, sinking to depths of over 500 feet is not advisable. As indicated by wells in Gloucester County on the west and across the Maryland line on the north, these deep waters are in all probability highly mineralized.

At Cape Charles the quality and volume of the water obtainable near the water front to a depth of 1,500 feet have been proven. Better water can probably be had by wells 20 to 80 feet deep driven east of the town, and larger yield by placing points at least 50 feet apart. The water found at 250 feet in sinking the deep well may repay investigation.

On the off-shore islands along the coast deep water prospects are not so promising as on the mainland, and on some of these islands cisterns will prove more satisfactory than wells.

NORTHUMBERLAND COUNTY.

General description.—Northumberland County, formed in 1648, occupies part of the eastern end of the Northern Neck, the peninsula between Potomac and Rappahannock rivers. The county faces Potomac River on the north and Chesapeake Bay on the east, and has a decidedly irregular outline.

Much of the county has the topography peculiar to the greater part of the Sunderland plain, a gently undulating surface, sharply cut by creek gorges. Altitudes on this plain are nowhere above 120 feet. Practically all streams draining the county flow to Potomac River or Chesapeake Bay, the county line on the south following the Potomac-Rappahannock divide.

Geology.—Columbia deposits mantle the surface. Miocene beds belonging to the St. Mary's formation are exposed at many points near Yeocomico, Great Wicomico, Little Wicomico, and Coan rivers. They are prevailingly sandy, gray to greenish or bluish in tint, and contain beds of shells. The Pamunkey, the Upper Cretaceous, and the Potomac beds are not exposed within the county; well records indicate that the bottom of the Chesapeake group lies 320 feet below tide water on the western boundary of the county and 600 feet below at Fleet Point. The base of the Pamunkey is 500 feet below tide water at Kinsale and 700 feet below at Fleet Point. The crystalline bed rock may be 1,500 feet below sea level at Kinsale.

UNDERGROUND WATERS.

Distribution and quality.—Ground water, abundant and potable, is found in the Columbia sands and in the top beds of the Chesapeake under most of the county. On the lower terraces many shallow wells go dry in time of drought. The quality of the water varies from soft and sweet to hard, irony, or brackish.

The deeper Chesapeake sands and the Pamunkey sands carry soft water under the whole county. There are artesian sands at the base of the Calvert, in the Nanjemoy formation, and in still lower beds, possibly Matawan. The heads of the flows range from 10 to 35 feet above sea level. The Chesapeake flows are soft, alkaline, and slightly sulphur-bearing. The Pamunkey waters much resemble the Chesapeake but have less sulphur odor. The Upper Cretaceous waters are harder than the Chesapeake and Pamunkey, and contain more lime salt.

Springs.—There are many springs of the usual Coastal Plain type along scarps, and in gorges and gullies. The majority flow from Columbia sands.

a few from shell beds in the Chesapeake group. The great majority are without improvements and are used only for watering stock. From none is water sold.

Wells.—On the higher terraces dug wells are lined with planks at the bottom and at the top, since the loams near surface are sandy. On the lower terraces wells are lined with planks or boards throughout. A small proportion of the wells are lined with brick; very few are cased with tile. On the lower terraces are a few driven wells, and along inlets from Potomac river and Chesapeake bay are many drilled wells. Most of these are of small diameter, under 2 inches, and go only to the first sand that will yield a flow. A few are of larger diameter, 2 to 6 inches, and go down more than 500 feet.

LOCAL SUPPLIES.

At Heathsville, the county seat, all the water used is obtained from dug wells 25 to 45 feet deep; in some wells it is hard.

On Yeocomico and Coan rivers most of the flowing wells get water from Calvert sands at 250 to 320 feet. A field assay of water from the Calvert flow at Coan on Coan River is given in table 8.

The wells on the Great Wicomico are among the most notable in Tidewater Virginia. They range in depth from 590 to nearly 700 feet, and are 2 to 6 inches in diameter. Most of them were drilled by the same contractor, R. H. Milligan, of Crisfield, Md. Through the kindness of Mr. Milligan the following record of a well at Reedville is published:

Record of 698-foot well of J. C. Fisher, Reedville.

(Authority, R. H. Milligan, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil, sand, gravel etc.....	60	60
Sandy clay	20	80
Blue clay	50	130
Dark marl (clay and sand, full of shells).....	133	263
Shell rock	8	271
Hard dark marl	101	372
Rock	2	374
Sand, water-bearing; sulphur water, flow not tested.....	26	400
Soft dark clay	8	408
Dark marl with thin crusts of rock.....	68	476
Hard rock	4	480
Tough dark clay	210	690
White micaceous sand, contains lignite, water-bearing; flow 18 gallons through a 2-inch pipe at 30 feet above tidewater....	8	698

Mr. Milligan also furnished the following notes on the formations penetrated below 670 feet by the well at Fleet Point.

Partial record of well of Fleeton Development Co., Fleeton.

(Authority, R. H. Milligan, driller.)

Material	Thickness (Feet)	Depth (Feet)
No record	672	672
Hard white sand containing a little water	20	692
Hard marl, with green clay below	17	709
Sand, water-bearing, flow at surface 15 gallons per minute through 3-inch pipe	1	710
Dark clay or marl	10	720
White sand, water-bearing, flow not tested	1	721
Red clay (a streak not over 1 foot thick and "red as paint" at 725 feet) turning brownish below	19	740
White sand lying in crusts, comes up in balls easily crushed with the fingers, water-bearing; flow 30 gallons per minute through 2-inch pipe	5	745

The red clay and the white sand below it correspond to those struck at Urbanna, in Middlesex County, at 520 to 590 feet.

The water from the deep wells on the Great Wicomico is used for general household purposes, but particularly for boiler supply and for cleaning at the fish factories.

The conditions reported at some places in Northumberland County, where dug and driven wells are the sole sources of supply, are summarized as follows:

Details of wells in Northumberland County.

Location	Depth of well (Feet)	Water bed	Quality of water
Blackwells	35-72	Sand and rock	Good
Brown's Store	20-35	Sand	Shallow, salty; deep, good.
Coan	8-80	Sand	Soft to hard
Cowart	10-14	Sand and gravel	Soft
Callao	35-50	Sand	Slightly hard
Fleeton	18	Sand	Soft, brackish
Hyacinth	40-50	Iron crusts and clay.	.....
Lottsburg	25-60	Iron crusts and sand.	Soft
Dynhams	8-20	Sand	Soft
Mila	14-50	Sand and marl	.....
Reedville	10-15	Sand	Soft
Rainswood	15-25	Sand	Soft
Sampson's Wharf	12-50	.....	Soft and hard
Tibitha	7-15	Sand	Good
Wicomico Church	10-80	.....	.....

Conclusions.—In Northumberland, as in other counties in the Virginia Coastal Plain, the development of ground water by dug wells is not always done with proper care. Though most wells, except those in villages, are not situated dangerously near privies and other sources of pollution, the protection of the wells at surface is usually altogether too slight. An abundant supply of artesian waters that will rise 35 feet above sea level can be had anywhere in the county by properly drilled and cased wells. The development of this water merits more attention than it has received, in spite of the many flowing wells in the county. At Heathville, soft water can be had by drilling 340 feet; it will have to be pumped as it will rise only to within about 40 feet of the surface.

PRINCE GEORGE COUNTY.

General description.—Prince George County, formed in 1702 from Charles City County, lies south of James River and the tidal portion of Appomattox River, east of Petersburg. The most thickly settled portion of the county is near Petersburg, which city is just across the county line in Dinwiddie County.

The county is near the western edge of the Coastal Plain, but, except along James River where the more important creeks, Baileys, Graves, and Chipoak, have cut short valleys, the topography differs from that of counties along the "fall-line" to the north. The headwaters of Blackwater River are only 5 miles from Appomattox River. Blackwater River flows into the Chowan, which empties into Albemarle Sound 150 miles to the southeast. Except near their mouths, the creeks flowing to the James have steep gradients; those flowing to the Blackwater and Nottoway have flatter gradients. The larger streams flow through narrow swamps 30 to 60 feet below an undulating sandy plain. The valley slopes are without steep descents. The highest points in the county are just south of Petersburg and have an elevation of 200 feet, but most of the county is comparatively low, a considerable portion being less than 100 feet above sea level. Terraces are clearly traceable along Appomattox and James rivers, but along the tributaries of Blackwater and Nottoway rivers the terraces grade into each other by slopes; scarps are not prominent. The greater part of the high ground of the county is included in the Sunderland terrace.

Geology.—The oldest visible formation within the county limits is the Patuxent of the Potomac group (Lower Cretaceous). Its characteristic arkosic sandstones and incoherent sands containing pebbles, cobbles, and clay balls, are exposed near Livetenant Run, a tributary of Appomattox

River, in the northwest corner of the county, and in various places near Appomattox River for 4 or 5 miles northeastward. The greensands and shell beds of the Aquia formation of the Pamunkey group (Eocene) outcrop on Livetenant Run near the Petersburg waterworks pumping station and at several places on James River, as in the bluffs at City Point. The Calvert formation of the Chesapeake group (Miocene) containing dark and light diatomaceous clays, and dark and light sandy clays, with shell beds, overlaps both the Pamunkey and Potomac. The base of the Chesapeake is 5 feet above sea level at Coggins Point, but is about 150 feet below at the mouth of Chipoak Creek, 10 miles southeast. Near Petersburg, the base of the Pamunkey is about at sea level, whereas at City Point, 6 miles northeast, it is about 20 feet below, and between is a wide stretch of country where Potomac beds are 50 feet above sea level. The base of the Pamunkey at the mouth of Chipoak Creek is about 300 feet below sea level.

UNDERGROUND WATERS.

Distribution and quality.—An abundance of water is stored in the Columbia sands and the upper beds of the Potomac and Pamunkey groups in the western part of the county, and the upper beds of the Chesapeake in the eastern and southern portions. The quality shows wide differences, but the water generally is soft. Relatively few deep wells have been drilled in the county, and little is known of the quality of the Patuxent and Potomac waters under more than 100 feet of cover.

Springs.—Prince George County contains numerous springs, but none of commercial interest. Some are used for household supply. One of the most noted is at City Point; it really consists of several springs developed by digging along the face of the bluff, and once supplied the hospital of Grant's army. It is now used by several families. The total flow is perhaps 50 gallons per minute. The water is clear, tasteless, and odorless, but, as it comes from shell beds in the Pamunkey, is slightly hard.

At Coggins Point a spring that flows from sand beds near the top of the Chesapeake supplies the residence of David Dunlop. The water is pumped by a gasoline engine from an enclosed masonry basin to an elevated tank, and is distributed thence to the dwelling house and other buildings. The flow is 25 gallons per minute. The water is clear, tasteless, odorless, and low in lime (for field assay see table 6).

Two springs are worthy of note. One, having a flow of 25 gallons per minute, is 2 miles west of Disputanta, the other is at Warwick Church a

mile farther west. Both springs flow from surface sands a foot or two above the level of the water in Warwick Swamp. Field assays of the waters are given in table 6. A spring near Garysville has been utilized for household supply by means of a ram.

Wells.—Dug wells that draw on water-bearing sands in the Columbia formations are the chief source of supply in villages and on farms. Most of them are cased with wood, a few with tile; near Petersburg are many deep, bricked wells. The cost of dug wells varies. At City Point the cost of wells 20 to 50 feet deep is \$2 per foot for digging and bricking. There are some driven wells and some bored wells. In places ordinary driven wells are unsatisfactory because of fine sand clogging the pipes and cutting pump valves.

LOCAL SUPPLIES.

At Prince George Courthouse only dug wells are used. These yield water that is said to be slightly hard. The lower part of Blandford, a suburb of Petersburg, is supplied with surface water from the Petersburg system. The dug wells on the high ground are 40 to 60 feet deep, and usually get soft water. On the lowland near Appomattox River driven wells get water of varying quality at depths of 20 to 25 feet, from Columbia or Potomac sands and gravels. At City Point, where dug wells 20 to 50 feet deep get hard water, a drilled well 112 feet deep obtains from Potomac gravels plentiful supplies of soft water that is sometimes turbid from clay in the water bed. Samples saved from this well served for the following record:

Record of well of the Misses Epes, City Point.

Material	Thickness (Feet)	Depth (Feet)
Soil, clay and sand (no sample)	40	40
Fine to coarse quartz sand with a little dark clay and much glauconite	15	55
Quartz sand, glauconitic, and coarse gravel, in light clay.....	20	75
Fine to coarse white gravel with a little arkosic sand, some glauconite	14	89
Fine gravel in white clay	33	112
Gravel and well-rounded pebbles up to 2 inches in diameter, with a little white clay; water-bearing.....	....	112

A complete analysis of this water, of interest because of the location of the well, is given in table 11.

At Coggins Point a well 307 feet deep passed through several water-bearing beds between 60 feet and the bottom, but could not get a flow, as the elevation of the well mouth is 63 feet above mean high tide in James River.

At Disputanta, people rely on dug wells about 14 feet deep which get soft water from red, buff and yellow loams of the Columbia group. As the loams stand well, many of the wells are not cased, having only 2 or 3 feet of wood curbing at the top. The average depth of the wells within a mile of Disputanta is 20 feet; the deepest well is 35 feet. In the vicinity of Wall's Store wells on slopes get hard water at 10 to 15 feet in marl, while those on high ground get soft water at 22 to 25 feet in white sand under red clay.

Information regarding dug wells at other points in the county is summarized herewith:

Details of dug wells in Prince George County.

Location	Depth of well (Feet)	Water bed	Quality of water
Academy	15-20	Loam and sand	Soft
Brandon			
Burrowsville	15-40	Shallow, sand; deep, marl.	Good and bad
Harrison Grove Corner	32	Sand	Soft
Edlow	20-30	Sand	Soft
Garysville	20-40	Sand	Soft
Templeton	15-40		Irony
Spratleyville	30	Sand	Soft
Youngblood's Store	20-35	Sand	Soft

At Spratleyville a bored well near the store went through soil 2 feet; variegated clay, 15 feet; yellow sand, 18 feet; coarse white gravel—water-bearing—1 foot. Near Garysville wells on high ground go through soil, 1 foot; red clay, 10 feet; yellow sand with cobbles, 3 feet; “pipe” clay and red clay, 10 feet; and get water from white sand.

Conclusions.—As the western side of Prince George County is near the edge of the Coastal Plain, there is slight chance of obtaining flowing wells except along James River east of City Point. Flows with heads of 10 to 25 feet above tide can be had from Pamunkey and Potomac beds on low-ground near the river east of Baileys Creek.

At Prince George artesian water can be had from the Potomac beds by pumping; the water will rise to about 35 feet below the level of the Court-house. At Disputanta, the artesian waters in the Pamunkey and Potomac sands will rise to about 40 feet below the level of the railroad station. Hence there is no chance of getting flows.

PRINCESS ANNE COUNTY.

General description.—Princess Anne County, formed in 1691 from Norfolk County, is bounded on the north by Chesapeake Bay, on the east by the Atlantic Ocean, on the south by the North Carolina line, and on the west by Norfolk County. The only incorporated town in the county is Virginia Beach, a noted resort.

The surface of Princess Anne County is flat and is included in a low terrace. At the northwest, between the eastern branch of Elizabeth River and Lynnhaven Inlet, the surface in places rises 25 feet above mean sea level, but much the greater part of the county has an elevation of less than 20 feet. The highest points are on the sand dunes near Cape Henry, over 75 feet high. The county contains considerable tracts of swamp and marsh land. Shallow lagoons with wide stretches of salt marsh lie back of the barrier beach that extends from a few miles south of Virginia Beach to the North Carolina line. The principal streams are tidal and have marshy shores.

Geology.—No formations older than Columbia beds are exposed. The youngest Columbia formation, as shown by well records, is probably 75 feet thick. It comprises buff loams and light-colored sands, underlain below water level by soft, dark clays, termed marsh mud by well drillers, sands and shell beds.

Below the Pleistocene beds lies the Chesapeake group, the upper part of which shows by well records not less than 250 feet of dark, sandy clay, which contains continuous sand beds and beds of shell marl, but in general is dense and impervious. Pamunkey, Upper Cretaceous, and Potomac beds underlie the Chesapeake in order. Crystalline bed rock is over 2,200 feet below sea level.

UNDERGROUND WATERS.

Distribution and quality.—Water lies near the surface in Princess Anne County, and abundant supplies can be had almost everywhere, but the quality at many places is not satisfactory. The shallow water where the water table is just below the surface is in many places of objectionable color or odor, and is not considered healthful. In some places this water is iron-bearing, and, along tidal inlets and on the barrier beaches, it is brackish. The waters, 15 to 50 feet below surface, are less liable to be polluted and are preferred. In places they are irony or brackish, and as a rule are hard. The discontinuous sands near the top of the Chesapeake group have been little prospected. The quality of the deeper flows, as

shown by the well at the Norfolk City Waterworks pumping station, has already been discussed. (See page 110 et seq.)

At their best, the Columbia supplies are soft and clear, and as good drinking water as can be desired. At their worst, they are so highly colored, hard, iron-bearing, and salty as to be unsuited for most purposes.

Springs.—There are few springs in Princess Anne County; one of commercial importance is Diamond Spring, situated on land owned by C. F. Hodgman, a quarter of a mile east of Waterway. The water issues from Talbot sands at the foot of a slight descent to an arm of Lake Lawson, and the flow is said to vary but little during the year. The water has been sold in Norfolk. The following sanitary analysis was furnished by the owner:

Analysis of water from Diamond Spring near Waterway.

(C. F. Chandler, analyst.)

	Parts per 1,000,000
Total solids	36.4
Organic and volatile	12.5
Chlorides	10.5
Chlorides as sodium chloride.....	17.4
Phosphates	0.0
Nitrogen as nitrates and nitrites.....	1.55
Permanent hardness, equivalent to CaCO ₃	13.1

The sanitary surroundings of this spring in 1906 were excellent.

Other springs are those of E. B. Macon and W. B. Strong, 2 miles west of Virginia Beach, which have been used for domestic supply.

Wells.—Driven wells are the principal source of water supply. Many of them are inexpensive, being driven by a maul to the first water-bearing sand and finished with a pitcher pump. The yields vary greatly. Where the ground water is iron-bearing and corrosive the yield is much reduced within a few years by rust clogging the pipe. Wells finished with brass gauze, or slotted brass screens, and good pumps maintain their yield much longer.

Dug wells are used chiefly for stock; because of their easy pollution they are recommended only for irrigation. Several deep wells have been drilled in the county; particulars of some are given in table 5.

LOCAL SUPPLIES.

The Norfolk County Water Co., which supplies part of the city of Norfolk and several suburban settlements, has its pumping plant on a tract

of land containing about 275 acres, some 5 miles northeast of Norfolk, and a mile east of Moore's Bridge. Here the company had driven or dug, previous to December 1, 1906, 36 wells, varying in depth from 30 to 40 feet; all cased with iron. Thirty of the wells are 6 inches in diameter, and 6 are 54 inches. Water normally stands 9 to 17 feet below the surface, which has an elevation of 15 to 25 feet. Below the light-colored Talbot sands are bluish sands containing shells and some dark bluish clay. One well driven 50 feet as a test found no water in these beds. The following average section was given from memory:

Average record of wells of Norfolk County Water Co., Waterway.

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Fine yellowish sand	3½	4½
Yellow and brownish coarser sand with some gravel.....	10	14½
Fine white sand	2½	17
Medium coarse light yellow sand	16	33
Fine bluish sand with shells, sticky bluish mud below.....	17	50

Before locating its pumping plant, the company tested several tracts of land north and east of Norfolk, driving possibly 30 wells in all. The present site was selected because of the yield and quality of the water obtainable. An analysis in table 7 shows, according to the company, the average quality of the ground water in the vicinity of its wells.

The pumping plant of the Norfolk City Waterworks is a little more than a mile southeast of the Norfolk County plant. The supply is from shallow ponds, connected by canals. These canals in places went through shell beds lying apparently from 5 to 10 feet below water level. At the pumping station is a deep, artesian well, described on page 110.

At Virginia Beach, which has a population of possibly 5,000 during the height of the bathing season, several attempts to get artesian water have been made. One in 1890 found no water that would rise 10 feet above sea level though the well went down 350 feet. Another well driven some years later at the Princess Anne Hotel obtained water of fair quality at 90 feet. This water did not rise to surface, but to about sea level. In 1906, supplies at the Beach were obtained from shallow wells driven 5 to about 30 feet, estimates of maximum depth varying considerably. The first water is found in sands below buff or yellow clay. The following record was given as a fair average of the materials penetrated:

Well at Virginia Beach.

(Authority, J. L. Walker.)

Material	Thickness (Feet)	Depth (Feet)
Sandy soil	1	1
Yellowish and reddish clay	10	11
White sand and blue clay in alternating strata, 2 to 4 feet thick	16	27

Most of the wells have hand pumps, some have wind pumps, and a few steam or gasoline pumps.

Some wells yield soft and some yield hard water. Many, near the ocean, yield slightly brackish water. At nearly all wells the water contains some iron, at a few it contains little. Cistern water is largely used for drinking. A field assay of a sample from what was said to be one of the best wells on the beach appears in table 7.

At Cape Henry driven wells, 10 to 20 feet deep, and cisterns are used. Some of the wells yield soft water, but at most the water is highly colored and at some brackish. Along the ocean beach from a few miles south of Virginia Beach to the North Carolina line there is no good well water. Between Lynnhaven and Broad bays clear, soft water is reported at 15 to 25 feet, in sand below red clay and sandy surface soil. Dug and driven wells at other points obtain supplies that vary in quality from place to place. Some conditions reported are here recorded:

Details of wells in Princess Anne County.

Location	Depth of well (Feet)	Water bed	Quality of water
Bonney	12-15	Sand	Good
Herbert	25	Sand	Irony
Jacksondale	8-30	Sand	Shallow, soft; deep, hard and irony.
London Bridge	10-20	Sand	Shallow, irony; deep, good.
Lynnhaven	10-18	Sand	Soft, hard, irony
Mapleton	10-15	Shallow, clay and sand; deep, mud.	Shallow, good or brackish; deep, hard and irony.
Nimmo	10-15	Sand	Good
Sigma	20-25	.....	Slightly brackish

Conclusions.—Enough driven and drilled wells have been sunk in Princess Anne County to show average prospects. Excellent water can be

had near the surface at many points, at other points cistern water or water from ponds or lakes will be found more satisfactory. More attention should be given the location of shallow wells, and the indiscriminate driving of wells 10 to 20 feet deep in the immediate vicinity of privies and cesspools should not be tolerated. Deep drilling in the hope of finding potable water from the basal Chesapeake (Calvert), Pamunkey, Upper Cretaceous, or Potomac sands is inadvisable; in fact, will in all probability prove a waste of effort.

At Virginia Beach the possibility of getting water of satisfactory quality from driven wells in vacant land away from tidal inlets had received little attention up to 1906. The supply of the town must come either from such shallow wells or from ponds.

An adequate supply for the municipal waterworks of Norfolk can be more easily and cheaply obtained from streams than from wells.

PRINCE WILLIAM COUNTY.

General description.—Prince William County, formed in 1730, lies on the west side of Potomac River above the big bend. Only a small part of its area, a strip along the river containing about 80 square miles, lies within the Coastal Plain province.

Lying on the slope from the Piedmont Plain to Potomac River, with differences of altitude of over 300 feet, the Coastal Plain area has been deeply eroded and the topography is rough and broken. Except for a few strips on the lower terraces near the river there is little level ground. Patches of the Lafayette terrace back of Quantico are 300 feet above sea level, but intermediate terraces are traceable with difficulty. The drainage in the Coastal Plain section is in creeks tributary to Potomac River, of which Occoquan Creek, which forms the northern boundary of the county, is the most important.

Geology.—Overlying the crystalline bed rock, which is exposed along the upper courses of the creeks, are the gray arkosic sands and sandstones, and drab and brown clays of the Patuxent formation of the Potomac group (Lower Cretaceous). Except for small scattered patches the Pamunkey (Eocene) greensands and clays have been removed by erosion, and the Chesapeake (Miocene) beds have been entirely removed. The cobble beds, sands, and bright-colored loams of the Columbia formations, and the Lafayette, hide the Potomac beds in many places.

UNDERGROUND WATERS.

The Patuxent formation, as shown by deep wells near the river, contains water-bearing sands that vary in thickness, lateral extent, and yield to wells. At most places one or more sands yield good water freely. Ground waters reached by dug, bored, or driven wells, lie in Columbia, Lafayette, or Potomac sands, at varying depths according to the location of the wells. As a rule the water is soft.

Springs are numerous. Little use is made of most of them and none are now of commercial importance. One, that of J. R. King, a mile north of Dumfries, was a resort of some note 50 years ago.

LOCAL SUPPLIES.

Artesian wells have been sunk at Myron (Cherry Hill), Quantico, and at a point 5 miles north of Quantico. The following record of the well at Myron was obtained from N. H. Darton.

Record of well at Cherry Hill.
(Authority, W. C. Miller, driller.)

Material	Thickness (Feet)	Depth (Feet)
Top soil	2	2
Sand and gravel	41	43
Sandy clay	47	90
Yellow sand and gravel with water	22	112
No record	15	127
Yellow sand and gravel, some water	6	133
Blue clay mixed with sand, some water	8	141
Blue and brown clay	16	157
Blue sandy clay	8	165
No record	2	167
Fine sand with water	18	185
Blue clay, mixed with a little sand.....	53	238
Coarse sand with gravel, plenty of water.....	14	252
Blue clay and sand with rock (?) at 257 feet	5	257

The well yielded 50 to 60 gallons per minute during an 8-hour pumping test.

The water is soft and slightly iron-bearing, a yield by pumping of about 320 gallons per minute through a 4-inch pipe is reported.

The well at Quantico is 210 feet deep. Darton^a has published this record:

^aDarton, N. H., Op. cit., 1896. p. 177.

Record of well at Quantico.

Material	Thickness (Feet)	Depth (Feet)
White clay	22	22
Fine gravel	6	28
Red clay	25	53
Fine red sand	5	58
Very hard blue clay	28	86
Fine sand	3	89
Dark clay	35	124
Coarse dark sand	3	127
Light-colored clay	78	205
Very coarse sand and water	5	210

This well, 4 inches in diameter, flowed 30 gallons per minute at 10 feet above the river. The head is said to have been 22 feet. The water is used by a number of families in the village.

The well 5 miles north of Quantico was sunk for the projected town of Barrow, and is little used. Water was struck in a bed of sand, or sandstone, at 143 feet. The following record has been published:^a

Record of well at Barrow.

Material	Thickness (Feet)	Depth (Feet)
Clay and marl	10	10
Gravel	10	20
Clay	10	30
Sandstone	14	44
Coarse sandstone, water-bearing	1	45
Sandstone	12	57
Bluish sandy clay	1	58
Brown clay	15	73
Bluish sandy clay and fine sand	40	113
Sandstone, large supply of water	30	143
Yellow clay	4	147
Sand with pebbles	13	160
Yellow clay	5	165
Brown clay	30	195

Some reported depths of dug wells and the supplies obtained are as follows:

Details of dug wells in Prince William County.

Location	Depth of wells (Feet)	Water bed	Quality of water
Agnewville	25-65	Gravel	Soft to irony
Dumfries	20-80	Shallow, iron crusts; deep, clay	Soft, hard, irony
Neabsco	20-30	Sand	Soft

^aDarton, N. H., Op. cit., 1896, p. 177.

RICHMOND COUNTY.

General description.—Richmond County, formed in 1692 from old Rappahannock County, is in the Northern Neck, the peninsula between Potomac and Rappahannock rivers. The more important creeks, Monatigo and Totuskey, drain into the Rappahannock. The topography resembles that of many counties north of James River. The creeks head in sharply cut valleys and are tidal and bordered with salt marshes along their lower courses. The maximum altitude of the Sunderland plain is about 150 feet, near Farmers Fork, and 100 feet near Downings.

Geology.—The loams of the Columbia formations are exposed in many road cuts. The dark, clayey sands of the St. Mary's formation of the Chesapeake group (Miocene) outcrop at numerous points along Rappahannock River and its tributary creeks. Pamunkey (Eocene) beds are not exposed, the base of the Chesapeake lying about 50 feet below tide in the northwestern corner of the county, and 300 feet below near Simonson in the southeastern part. Upper Cretaceous beds probably underlie the Pamunkey and are in turn underlain by Potomac. The bottom of the Pamunkey is probably 300 feet below tide at Carter's Wharf, and 450 feet below at Simonson. Bed rock lies fully 1,000 feet deep.

UNDERGROUND WATERS.

Distribution and quality.—The sands of the Columbia formations and the highest Chesapeake beds contain ground water that varies in quality from soft and clear to hard and irony. Near the middle of the Chesapeake in the Choptank formation and toward its base in the Calvert formation are coarse sands that yield artesian water. Other sands lie in the Nanjemoy formation of the Pamunkey. Heads vary from 20 to 35 feet above tide. Chesapeake and Pamunkey waters are soft and limpid, but the former have as a rule a slight odor of sulphur. The Chesapeake waters, as in Essex County across the Rappahannock, are less alkaline and contain more lime than farther east. At a number of places the substitution of artesian for shallow well water is said to have resulted in a marked improvement of the public health.

Springs.—Richmond County abounds in springs, but little use is made of them, except by stock. The springs are of small volume, seeps rather than bold flows, relatively few exceeding 5 gallons per minute. One owned by A. J. Snyder, near Blantyre, flows about 5 gallons per minute of soft water from iron crusts at the base of the Sunderland formation. There is no spring in the county from which shipments of water are reported, or is a resort.

Wells.—Dug wells are almost the sole source of supply on high ground. Many are cased with wood from top to bottom. At some of the old churches

and at old manor houses are bricked wells. Many of the shallow wells fail in prolonged droughts. Along Rappahannock River and tributary creeks are a considerable number of drilled wells, practically all of small diameter. The contract price for sinking about 275 feet ranges from \$50 to \$75. The actual labor cost of sinking, if everything goes nicely and no hard beds or "rocks" are encountered, may be \$25.

LOCAL SUPPLIES.

At Warsaw, on the Sunderland plain, water is obtained from dug wells 35 to 50 feet deep, of which there are about 30. The following is an average section of the beds penetrated:

General section at Warsaw.

Material	Thickness (Feet)	Depth (Feet)
Soil	5	5
Red clay	17	22
White sand	14	36
Red sand and clay	3	39
Rock, iron crusts	2	41
Fullers earth, dark blue clay .....	....	....

The white sand bed halfway down gives much trouble to wells cased with plank in the usual way. The average life of the plank, as it is above water level, is but 6 or 7 years, and replacing the casing when decayed is more or less troublesome.

Along Rappahannock River not less than 50 artesian wells have been driven, there being at least 17 at Sharp's Wharf alone. Depths vary from 165 to 366 feet, but most of the wells draw on sands in the Calvert formation 160 to 300 feet below tide. Summarized information is given in table 5.

The following record of a well at Naylor's Wharf is given by Darton^a:

Record of 366-foot well at Naylor's Wharf.

Material	Thickness (Feet)	Depth (Feet)
Surface deposits	20	20
Fullers earth	100	120
Marl	15	135
Rock strata, 1 to 15 feet apart, containing water	20	155
Black sand	15	170
Blue fullers earth	90	260
Dark orange-colored loam	15	275
Black sand, full of water, which rises to 35 feet above tide	50	325
Blue fullers earth, underlain by a soft rock layer, with water that rises to 45 feet above tide	60	385

^aDarton, N. H., Op. cit., p. 175.

This well is used for domestic supply and by a canning factory. The quality of the water, which rose from a black sand in the Aquia formation, is shown by the field assay in table 9.

At Sharp's Wharf, one of the most important oyster-shipping points on Rappahannock River, most of the flowing wells go about 240 feet below tide and get water in the Calvert formation, from the same sand beds that are tapped by the wells at Bowler's Wharf on the opposite shore of the Rappahannock. A few go 360 feet to the Nanjemoy, and at least one reaches an Upper Cretaceous (?) sand at 440 feet. The head of the 240-foot wells was originally 24 feet, that of the 320-foot wells is about 30 feet above tide. The water is used for removing the mud from oysters as they are brought from the beds, and for washing shucked oysters. The flows are also utilized to keep oysters from freezing in winter, a pile of several hundred bushels being kept through the sharpest frosts without injury by allowing the water, which has a temperature of 63° F., to flow over them.

At one of the wells near Wellford's Wharf, which draws on Choptank sands, the following beds were penetrated:

Record of 165-foot well of Frank Garland at Wellford's Wharf.

(Authority, Frank Garland, owner.)

Material	Thickness (Feet)	Depth (Feet)
Sand	5	5
Blue mud or "marl"	30	35
Gravelly sand	50	85
Thin strata of rock	55	140
Sand and rock, with hard rock stratum at 163½ feet; water in shell rock at 156 feet	25	165

This well, at an elevation of 6 feet, flows 24 gallons per minute. The head is about 22 feet above mean high tide, and is a foot lower at ebb than at flood tide.

Near Whealton are several wells that tap deeper sands in the Calvert formation.

Near the bridge across Totuskey Creek east of Warsaw, several flowing wells draw on Calvert sands at about 180 feet. The water is used for domestic purposes, in saw-mill boilers, and at a canning factory. It is called a fairly satisfactory boiler water though having a tendency to foam. Field assays are given in table 8.

The following record of a well higher up Totuskey Creek is of interest from the occurrence of a sand yielding artesian water at a depth of only

65 feet. This sand, which was found also in a dug well, is probably of limited extent.

Record of well of W. E. Garland, near head of Totuskey Creek, 5 miles east of Warsaw.

Material	Thickness (Feet)	Depth (Feet)
Surface wash	8	8
Blue marl, water at 65 feet	157	165
Rock	2	167
Blue marl	17	184
Rock	3	187
Sand (composed of medium quartz grains with much dark green to black glauconite): water, head at 30 feet.....	1	188

The flow is 16 gallons per minute through a 1½-inch pipe at 8 feet above river. This well was put down by the owner in less than a day. The water is used for household purposes. The overflow, received in a cement basin protected by a small building, prevents viands from freezing in winter and keeps them cool in summer.

Data collected at various places in the county regarding dug wells are given below:

Details of dug wells in Richmond County.

Location	Depth of well (Feet)	Water bed	Quality of water
Blantyre	20-50	Clay or sand	Hard
Carters Wharf	16-50	Loam and sand	Soft
Downings	35-45	.....	.....
Farmers Fork	25-60	.....	Good
Farham .....	.....	Sand or clay	Soft to hard
Haynesville	12-60	.....	Shallow, soft; deep, hard.
Ivondale	12-65	.....	Shallow, hard to soft; deep, hard.
Newland	18-45	Clay	Soft
Sharps	18-20	Clay and sand	Hard
Wellford	15-22	Sand	Soft

Conclusions.—Water that is perfectly healthful, so far as freedom from disease germs is concerned, can be had by dug or bored wells less than 50 feet deep at many points in the county, provided the wells are not located near sources of pollution, and are properly cased or lined, preferably with tile. Soft, iron-free, artesian waters can be had anywhere, but pumping will be necessary at places more than 20 to 35 feet above sea level.

At Warsaw, elevation 105 feet, good supplies can be had by sinking a 6-inch well to the Calvert sands about 300 feet below the level of the Courthouse. There is also a possibility of obtaining water in the sands at 225 feet down. From neither of these sands will the water rise to 50 feet of surface.

SOUTHAMPTON COUNTY.

General description.—Southampton County, formed in 1784 from Isle of Wight, lies between Sussex County and the North Carolina line, its north end being 30 miles southeast of Richmond.

The county has a rolling surface. It is traversed by Blackwater and Nottoway rivers, which unite to form the Chowan at the southeast corner of the county, and is bounded on the southwest by Meherrin River. These streams flow through rather open valleys and meander across low terrace plains, and their tributaries are called swamps. A large part of the surface is included in the Sunderland and Wicomico terraces. Later Columbia terraces can be traced along the river valleys, but their total extent is undetermined. The maximum elevation of the highest terrace is about 110 feet near Joyner, Ivor, in the northern part of the county, has an elevation of about 90 feet. The highest ground in the vicinity of Franklin is 84 feet above sea level. In the valleys of Meherrin, Nottoway, and Blackwater rivers in the southern part of the county, a low Columbia terrace, with an elevation of 20 to 25 feet above tide water, covers large areas. The extent of the low terraces, those less than 40 feet above tide, is an important question since it is along them that flowing wells are to be had.

Geology.—The sandy loams of the Columbia formations hide the older deposits over nearly all the county, the Chesapeake (Miocene) sands and marls being exposed here and there on valley slopes. The base of the Chesapeake is about 20 feet above sea level in the west end of the county and 120 feet below near Franklin, evidently dipping eastward about $4\frac{1}{2}$ feet per mile. The Chesapeake thins to feather edges at the west, but is 200 feet thick on high ground in the northeast end of the county. The Pamunkey (Eocene), Potomac (Lower Cretaceous), and Upper Cretaceous beds underlie the Chesapeake group under part of the county, but toward the southwest the Pamunkey beds thin out and disappear and the Chesapeake rests directly on the Potomac. Even at Franklin there is no positive evidence that the Pamunkey is present. At Emporia, in Greenville County, 2 miles west of the west corner of Southampton County, crystalline bed rock comes above sea level, so that the thickness of the

Potomac and Upper Cretaceous beds in Southampton County varies from almost a feather edge to possibly 900 feet at Franklin.

UNDERGROUND WATERS.

Distribution and quality.—The Columbia sands carry plenty of water, which at many places is hard; in low ground the shallow water is not considered healthful. The depths to the water table vary with differences in topography, but in general water lies not more than 20 feet below surface. In the southern, eastern, northern, and western parts of the county artesian waters under heads of 25 to 50 feet above tide are found, in the sands of the Potomac group or of the Upper Cretaceous; well drillers say the sands at Arringdale, Hugo, Branchville, Boykins, Delaware, Courtland, and Franklin are white and contain much mica, and more or less lignite, called "wood" or "coal." In places the sands are apparently arkosic. As no fossils have been saved from bore holes, the exact age of the sands is in doubt. Similar sands are reported at Margaretsville, on Meherrin River in North Carolina. The artesian waters show considerable differences. In general they are soft and alkaline and well adapted to household use, but at some places they contain iron and have a distinct sulphur odor.

Springs.—While there are in the aggregate many springs along the creeks of Southampton County, most of them issue as seeps rather than strong flows, and in some sections of the county springs are relatively scarce. A few are used for household supply but none are of commercial importance.

Wells.—Southampton County probably contains more drilled wells than any other county of Tidewater Virginia except King William. The total number may exceed 300. Nearly all are $1\frac{1}{2}$ or 2 inches in diameter. Depths range from 75 to 344 feet, and costs from 25 to 50 cents per foot. On the higher ground dug wells are the main source of supply for farms and villages. The usual price for digging is \$5 for 30 feet. There are some bored wells and many driven wells in the county.

LOCAL SUPPLIES.

At Branchville are about 17 wells that develop a water-bearing sand in Potomac or Upper Cretaceous beds. The depths range from 130 to 250 feet and the heads are 45 to 50 feet above sea level, the level of the railroad station being taken as 46 feet. The flows are from 1 to 8 gallons per minute. As many as four flows have been found by one well.

The following general section at Branchville is reported by R. G. Ellis & Son, well drillers.

General section at Branchville.

Material	Thickness (Feet)	Depth (Feet)
Surface soil, sand and clay	10	10
Yellowish sand, water	11	21
Soft blue mud	13	24
Blue marl, with shells	17	41
Sand, with lignite	9	50
Red and white clay, with sand layers.....	60	110
White sand, contains mica and lignite and at some wells much kaolin, water-bearing	45	155

Other water-bearing sands lie below, separated by clayey beds. The well of T. J. Harrell found flows at 90, 110, 160, and 207 feet.

The artesian water is of good quality, although having a faint sulphur odor and being slightly iron-bearing at some wells.

At Boykins, 3 miles east of Branchville, about 25 wells, mostly for household supply, have been driven to Upper Cretaceous or Potomac beds, the succession of surface soil, clay, sand, blue mud, marl, reddish clay, and sand being much the same as at Branchville. The wells range in depth from 85 to 130 feet. The water is soft, but at some wells carries a little iron and is sulphur-bearing. An idea of its mineralization may be had from the field assays in table 8.

Near Arringtondale are several small diameter wells that get flows from white micaceous sands below clay and marl. The wells go 70 to 75 feet below the surface of a swamp, elevation about 70 feet. They are used for household supply and for stock.

The Tidewater Railway Co. (Virginian Railway) has at Sebel the largest and deepest well reported in the county. It is 10 inches in diameter and goes down 344 feet. It probably draws on Potomac sands. The following record was kept by the driller:

Record of well of Tidewater Railway Co., Sebel.

(Authority, Tidewater Railway Co., owner.)

Material	Thickness (Feet)	Depth (Feet)
Clay	10	10
Clay and sand	20	30
Light blue mud	21	51
Blue mud and sand	10	61
Blue mud	51	112
Sand and gravel	10	122
Blue clay	32	154
Sand and clay	13	167

Record of well of Tidewater Railway Co., Sebel—(Continued).

Material	Thickness (Feet)	Depth (Feet)
Blue clay	8	175
Fine yellow sand	11	186
Blue clay and sand	5	191
Coarse sand and gravel; water.....	21	201
Hard blue clay	4	206
Dark mucky clay	18	224
Blue clay	12	236
Soft mucky blue clay	53	289
Blue clay	53	342
White sand and water-worn gravel with pebbles the size of a small egg; water-bearing .....	....	342

The water level of this well when completed was 21 feet below surface, elevation 55 feet. For a test the well was pumped steadily 18½ hours at the rate of 106 gallons per minute. This lowered the water to 48 feet below surface, but after pumping ceased the water rose gradually to within 15 feet of surface. The well was drilled for locomotive supply. The water contains sodium bicarbonate, as indicated by the analysis in table 7d, and has a tendency to foam. The water at 191 to 202 feet rose to 30 feet of surface.

At Ivor on high ground, 4 miles west of Zuni, the Shaw Lumber Co. sunk a deep well to procure supplies to supplement those obtainable from dug wells. It draws on Upper Cretaceous or Potomac sands. The following log is reported:

Record of well of Shaw Lumber Co., Ivor.

(Authority, Shaw Lumber Co., owners.)

Material	Thickness (Feet)	Depth (Feet)
Earth, marl, quicksand and blue mud.....	106	106
Blue mud and clay.....	89	195
Green mud	6	201
Black sand and gravel, with a small supply of water.....	19	220
White sand and small gravel.....	17	237
White sand with layers of blue mud.....	19	256
Water-bearing sand	31	287

The water from the bottom rises to 35 feet of the surface; the yield by air-lift is 55 to 60 gallons per minute. The 6-inch casing is finished with a No. 6 Cook strainer, 20 feet 6 inches long.

At Courtland are many flowing wells, possibly 75. T. J. Moore, of Storeys, reports having put down more than 50. Yields average about 10 gallons through a 2-inch pipe at surface, but vary from 1 to 50 gallons,

depths and yield depending partly on the elevation of the well. Where wells are thick, yields and heads have been reduced by interference, those on low ground draining those on higher ground. The original head was about 27 feet above sea level, and on the high ground, elevation about 30 feet above the Nottoway River, wells have to be pumped. The following general record is reported by Mr. Moore:

General section at Courtland.

Material	Thickness (Feet)	Depth (Feet)
Soil, clay and sand; water at 6 feet.....	13	13
Blue mud	23	36
Marl and blue mud	60	96
Yellow pipe clay	24	120
White micaceous sand with "wood," water-bearing, water rising about to surface	2	122
Yellow pipe clay	8	130
White micaceous sand with "wood"; water at 130 feet rising 12 feet above surface.....	15	145

A 2-inch well at the level of the main street, about 20 feet above Nottoway River, flows 25 gallons per minute. The artesian water is of excellent quality for household use, containing very little iron and having no sulphur odor. In a boiler it foams. Results of a field assay appear in table 8.

At Franklin a large number of wells have been put down, perhaps 150. Depths average 130 feet, but vary since surface elevations in the town range from 10 to 35 feet above river level. The water comes from higher sands than those tapped by the Courtland wells, and are presumably of Upper Cretaceous age. The following succession is reported by T. J. Moore:

General section at Franklin.

Material	Thickness (Feet)	Depth (Feet)
Soil clay and sand	15	15
Blue mud	20	35
Blue marl and shells	40	75
Blue pipe clay	25	100
Hardpan or marl rock; drilled 14 inches in 3 days.....	1	101
Dark clay, like blue mud above	30	131
Hardpan, or marl rock	$\frac{1}{2}$	$13\frac{1}{2}$
Clay and sand	$8\frac{1}{2}$	140
Hardpan or marl rock	$\frac{1}{2}$	$140\frac{1}{2}$
White micaceous sand, with "chunks of wood," water-bearing	$24\frac{1}{2}$	165

The average flow of 2-inch wells at the level of the main street, 20 feet above high tide in Blackwater River, is 4 gallons per minute. On "the ridge," the higher ground in town, elevation over 34 feet, the wells have to be pumped, as the water will not rise over 26 feet above high tide.

Flowing wells have also been drilled on Meherrin River west of Branchville, at Hugo, and south of Boykins, on Nottoway River several miles north and south of Courtland, and on Blackwater River as far north as Zuni, though no wells are reported on the Blackwater between Zuni and 5 miles from Franklin; south of Franklin deep wells are reported for 5 miles.

The following statement summarizes the information collected regarding dug wells at various places in the county:

Details of dug wells in Southampton County.

Location	Depth of well (Feet)	Water bed	Quality of water
Aidyl	15-30	.....	Soft
Assamoosick	6-60	Loam, sand and marl.	Soft
Conley	15-20	.....	Fair to good
Ivor	10-17	Blue clay	Soft
Maury	10-40	.....	Soft
Newsoms	10-30	.....	Soft
Sunbeam	15-25	.....	Soft, hard; deep, irony.
Unity	12-16	Sand and marl	Soft to hard
Worrells	22	Sand	.....

Conclusions.—Enough drilling has been done to indicate that flowing wells of good water can be had in this county on the low terraces along Blackwater River below McClelland, along Nottoway River below 10 miles north of Courtland, and along Meherrin River below 10 miles east of Emporia. Flows are not to be expected on the higher divides between the main rivers, but can be had up many tributaries for considerable distances. Where, as at Courtland or Franklin, heads have fallen and flows grown smaller by allowing wells to run without restraint more water can be had by going deeper.

SPOTTSYLVANIA COUNTY.

General description.—Spottsylvania County, formed in 1720 from Essex, King William, and King and Queen counties, lies between Rappahannock and North Anna rivers. Only a small part of the county near the eastern border is included in the Coastal Plain. The topography of

this portion of the county is as a whole hilly, but there are extensive level stretches 50 to 70 feet high along Rappahannock River, and also on the high Lafayette plain, which has an elevation of 250 feet south of Fredericksburg.

In the valleys of the main streams west of Fredericksburg the crystalline gneisses and granites are exposed. They are overlain by the arkosic gravels and sands of the Potomac (Lower Cretaceous) and further south by the sandy clays and sands of the Chesapeake (Miocene). Near Massaponax Creek, Pamunkey (Eocene) greensands weathered to reddish and buff tints separate the Potomac from the Chesapeake beds. The Columbia cobble beds, sands, and loams rest in places directly on bed rock, in places on Potomac, in places on Pamunkey, and in places on Chesapeake beds. The Potomac group has a maximum thickness of 300 feet in the extreme northeast corner of the county. The Pamunkey and Chesapeake are thinner. The Chesapeake is everywhere above sea level, and only a small portion of the Pamunkey is below.

UNDERGROUND WATERS.

Distribution and quality.—The coarser beds of the Lafayette and the several Columbia formations are the most important reservoirs of ground water. The supplies generally are soft and slightly mineralized, but in places the water in the 60-foot terrace formation is decidedly iron-bearing. In the Pamunkey and Chesapeake sands the water varies from hard to soft. Little is known of the Potomac sands below tide level.

Springs.—Because of the water-bearing sands in the Lafayette and lower-lying terrace formations being uncovered along scarps, springs are numerous. Most of them are small, a few show bold flows and several in the vicinity of Fredericksburg have been long used by the public. Two of these, known as the Mint and the Gunnery springs, are owned by the city. They have covered masonry basins which exclude trash and surface wash during storms. Each spring flows from the base of a terrace, and the terrace immediately back of each spring is rather densely populated. The water from neither spring can be regarded as safe from pollution, though the danger at the Gunnery spring is less than at the Mint spring. In 1906, the water from both springs was drunk by a considerable number of people, particularly in the summer, because of its coolness and clearness.

Another spring, known as the Silk Mill spring, issues from the base of the same terrace, near the river, in the northwest part of the city. It has been used more or less by people living in the vicinity, but an investigation

by the local Board of Health in 1905 indicated that the spring water was dangerous and should not be drunk unless boiled.

Besides these springs, several near the base of the Lafayette scarp on the heights a mile west of the city are utilized for public service by the Aqueduct Water Co. The water is clear and soft.

Wells.—Dug wells are the main source of supply. Depths vary greatly; in hollows on the top of the high Lafayette terrace are wells less than 15 feet deep, while near the edge of the terrace depths range up to 40 feet. Along lower slopes depths are from 20 to 30 feet.

On the broad terrace plain along Rappahannock River southwest of Fredericksburg, wells are dug to depths of 10 to 15 feet. In Fredericksburg is a number of dug wells 20 to 40 feet deep. Several near the river front, used for boiler supply, obtain rather hard water from Potomac beds.

In 1906, there was but one deep well in the city of Fredericksburg, that owned by E. D. Cole. This well is 120 feet deep and yields water of low mineral content. Mr. Cole uses the water for household purposes and furnishes it for drinking to neighbors who desire water more refreshing and less liable to pollution than that from the turbid Rappahannock. An analysis furnished by the owner, but recalculated to standard form, appears in table 11.

Fredericksburg is supplied with raw Rappahannock River water distributed by the city waterworks. In addition a private corporation, the Fredericksburg Aqueduct Co., distributes the water from the springs on the heights back of the town to a limited number of subscribers. This company is one of the oldest water companies in the United States giving an uninterrupted service, the springs having been developed as far back as 1823. Water was distributed for many years through bored logs and lead pipes. With ordinary care in maintaining the pipes leading from the springs to the supply basin, and in protecting the latter, these springs can furnish a drinking water of satisfactory quality, so long as the terrace above them is sparsely inhabited; but the flow is so small that the use must be limited.

Conclusions.—The gravels and sands, and even the non-clayey beds on the terraces along the river and on the divides, yield water in sufficient quantity for all the requirements of isolated dwellings and farm supply. Deep wells at and southeast of Fredericksburg will probably get good water from the Potomac beds. Flows can not be expected on the 60-foot terrace, though the water may rise above tide level.

STAFFORD COUNTY.

General description.—Stafford County, formed in 1765 from Westmoreland County, lies on the west bank of Potomac River north of Rappahannock River which forms its southern boundary. The Coastal Plain portion is a narrow strip along Potomac River.

Valleys deeply cut by Potomac, Aquia, and other creeks emptying into Potomac River give a rugged topography with comparatively few stretches of level ground. The maximum elevation, a little over 250 feet, is on a patch of the Lafayette plain, northeast of Fredericksburg. There are some level stretches on a low Columbia terrace along Potomac River, with elevations of 35 to 45 feet. Near the mouth of Aquia and Potomac creeks are cliffs 50 to 100 feet high.

Geology.—The soil over most of the Coastal Plain portion of Stafford County is derived from the Potomac (Lower Cretaceous) clays, shales, sands, and gravels. In places the Pamunkey (Eocene) greensands, weathered yellow, orange, and red, form the surface material, the largest area of Pamunkey being in the extreme southeast corner of the county. In this same part of the county a thin sheet of the Chesapeake (Miocene) rests on the Pamunkey, the only occurrence of Chesapeake beds in Stafford. The Lafayette and Columbia cobble beds, sands, and loams, as a rule brightly colored, rest on Potomac, Pamunkey, and on Chesapeake beds. The maximum exposed thickness of the Potomac is about 250 feet, and its thickness in the southeast corner of the county may be 350 feet. Nearly all the Pamunkey beds lie above sea level and no Chesapeake beds extend below it.

UNDERGROUND WATERS.

Springs are numerous but few are of especial note. They and dug wells are the sources of domestic supply. Depths to water and quality of water vary from place to place; in general the ground water is good. Excellent water can be obtained, no doubt, from the Potomac beds, but no deep wells have been sunk to determine the depth to water-bearing sands or the quality of the water. Flows are not to be expected.

Dug well conditions at a few points in the Coastal Plain portion of the county are summarized as follows:

Details of dug wells in Stafford County.

Location	Depth of well (Feet)	Water bed	Quality of water
Brooke	15-40	Sand and marl	Soft to slightly hard.
Falmouth	15-30	Sand	Soft to hard
Leeland	20-50	Sand	Soft
Millin	20-100	Soft rock and sand	Soft
Stafford	25-50	Sand and rock	Soft and hard

SURRY COUNTY.

General description.—Surry County, one of the original eight shires of Virginia, lies south of James River, in the western part of the Coastal Plain. Most of the surface of the county is included in the Sunderland plain and is rolling, with a gentle slope to the southeast. Near the northern edge of the county Chipoak, Grays, and other creeks flowing to James River have cut sharp valleys. As in Prince George County to the west, the southward flowing streams, such as Cypress Swamp, tributaries of Blackwater River, have open valleys. The divide is but a few miles back from James River. The Sunderland plain is, as a rule, below 100 feet high, its maximum elevation near Ruffins and Spring Grove being 130 feet. Low terraces occupy a very small part of the county. They are most noticeable south of Hog Island. For considerable distances, the southern bank of the James is steep and high, and the river cuts directly into the Sunderland terrace, as at Claremont.

Geology.—The Columbia (Pleistocene) formations cover most of the county. The Chesapeake (Miocene) group outcrops in the bluff at Claremont and is exposed in creek gullies. South of the divide the Chesapeake shell beds have been dug for marl in pits along tributaries of Blackwater River. The maximum thickness of the Chesapeake group in the western corner of the county is probably 150 feet, its base lying 50 feet below tide. In the eastern part of the county near Hog Island the base of the formation may be 350 feet deep. The Pamunkey does not outcrop within the county limits. Its base is about 350 feet below sea level at Claremont and 500 feet below at Homewood. The Potomac is over 500 feet thick and crystalline bed rock is fully 800 to 1,500 feet below sea level.

UNDERGROUND WATERS.

Distribution and quality.—Surry County is well watered by its numerous creeks. The ground water in the Columbia beds is generally soft, but in places is of indifferent quality. Ground water in the Chesapeake marls is at many places hard. Depths to water vary greatly. In the wide pocosons on the east side of the county the water rises to the surface after wet seasons, and is never more than 10 feet below it, while on high ground overlooking James River the water table may be 40 feet below the surface.

Plenty of artesian water underlies Surry County in the Chesapeake, Pamunkey, and Potomac sands. Both the Chesapeake and Pamunkey

waters are soft and are more or less alkaline. No attempt to reach Potomac sands is reported, but it is altogether probable that they will yield plenty of water.

Springs.—Surry County is abundantly favored with springs, nearly all the creeks and branches being spring fed. Many of the small springs and seeps fail in time of drought, but the deeper springs in the northern part of the county and the “boiling” springs in the southern part are perennial. Most of the springs are little used except by stock, but a few furnish household supplies. Near Claremont are several with bold flows. Some from beds of marl yield water that is slightly hard and is said to have a marly taste. There are people who consider such water unhealthful, but where the ground above the spring is thinly settled, the marl bed overlain by a thick layer of loam, and surface waters can not reach the sources of the spring through poorly protected dug wells, there is no reason for judging the healthfulness of the water by the taste. A complete analysis of water from a marl spring south of Claremont, given in table 6, shows that the water contains notable amounts of bicarbonate of soda. A marl spring north of the village supplies several families. Another spring just east of the city has been improved by the owner, E. E. Harry, who markets the water as Trepho Lithia water. This spring flows from iron crusts and sands in the Sunderland formation. Various improvements have been made at this spring, and precautions have been taken to maintain the sanitary excellence of its surroundings. The following analysis is recomputed from one furnished by the owner:

Analysis of Trepho Lithia water.

(J. B. Weems, analyst.)

	Parts per 1,000,000
Total solids	573.
Silica (SiO ₂)	34.3
Aluminum (Al)	1.95
Iron (Fe)	2.88
Calcium (Ca)	115.
Magnesium (Mg)	3.22
Sodium (Na)	11.2
Potassium (K)	2.12
Lithium (Li)	0.03
Bicarbonate radicle (HCO ₃)	395.
Sulphate radicle (SO ₄)	3.82
Chlorine (Cl)	3.46
Free carbon dioxide (CO ₂), 3.5 c. c. per liter.	

A group of marl springs just south of Dendron was, at one time, used for boiler supply at the mills of the Surry Lumber Co., but the water was

so limy and formed so much scale that the springs were abandoned. Other springs in the county deserving note are one, 2 miles southeast of Anchor, and one 2 miles northeast of Surry, on the road to Scotland. A few springs supply houses by rams; there is one at Bacon's Castle.

Wells.—Open dug wells, often provided with the old-time sweep and bucket, constitute the most important source of water for household use. Prices for digging these average about \$5. Most of them have no lining but a wood "curb" at the bottom. The cost of such wells complete has often been less than \$15. A few of the dug wells are bricked or cased with tile; the proportion of the latter is increasing. In dry seasons many of the shallow wells fail. There are some bored wells and some driven wells, and along James River a few drilled wells. At a number of points near the river the ground waters are so limy or irony that cisterns are used.

LOCAL SUPPLIES.

At Dendron most people obtain water from dug wells, 14 to 20 feet deep. There is also a considerable number of driven wells 18 to 20 feet deep, the water from which is considered better than that from dug wells. Both dug and driven wells get water from sands in the Sunderland formation. This water is soft and adapted to household use. A well drilled some years ago for the Surry Lumber Co. to a depth of 386 feet was abandoned as unsuccessful because it did not give a flow.

At and near Surry Courthouse dug wells average about 20 feet deep. Ordinarily they have from 5 to 8 feet of water in them, but in wet seasons some of the shallow ones are filled to the surface. Most of the wells are lined with wood, though a few are cased with tile. The following section is reported:

Section at Sunny Courthouse.

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Yellow clay	12	12
Slate-colored, sandy clay	8	20
Vari-colored clay, pebbles at 35 feet	20	40
Marl	3	43
White gravel; water	4	47

At Claremont, situated on a headland of the Sunderland plain, dug wells are from 20 to 40 feet deep. These yield water of varying quality; some is from shell beds and so hard as to be unsatisfactory for domestic

use. Some of the wells are liable to contamination because of insufficient protection at the surface, others because of seepage from old polluted wells nearby. In 1906, cisterns were used by fully one-half of the population; about one-fifth used wells; the balance used spring water. At some of these springs are rams supplying tanks at dwellings. The water is generally soft.

On Homewood plantation on Hog Island in James River are 6 flowing wells, all sunk 20 years ago. Their depths are variously stated, but all draw on Chesapeake beds. A 6-inch well is said to have been sunk 317 feet, and to have struck a strong sulphur water at 270 feet, and a good flow, 40 gallons per minute, in a shell bed at the bottom.

The following record of one of the wells has been published by Darton^a:

Record of well at Homewood.

Material	Thickness (Feet)	Depth (Feet)
Clay and loam	15	15
Gravel with surface water	10	25
Clay, blue below	60	85
Shell marl with hard crust of shell at base, flow of ferruginous water at 112 feet	37	112
Marl	108	220
Rock	1½	221½
Blue clay with flow of water at 222 feet, water better than at 112 feet, and greater flow	67½	289
Hard rock	2½	291½
Black, water-bearing sand; fine water, flow at surface 30 gallons per minute through 1½-inch pipe, head 40 feet.....	.....	291½

It is not possible to determine to which of the wells at Homewood this record refers.

A complete analysis from a well in the southeast corner of the plantation appears in table 8. The water has a faint sulphur odor when fresh. The well is said to be 219 feet deep; it may be deeper.

Another well south of Homewood and 4 miles east of Bacon's Castle was sunk for a brickyard, since abandoned. It is said to be 400 feet deep, but the water has all the characteristics of the Chesapeake flows. An attempt to get a flow at Bacon's Castle was unsuccessful, the elevation of the post-office being 84 feet above tide.

Shallow well conditions at a number of villages in Surry County are summarized below:

^aDarton, N. H., *Op. cit.*, p. 174.

Details of shallow wells in Surry County.

Location	Depth of well (Feet)	Water bed	Quality of water
Alliance	15-40	Marl	Shallow, soft; deep, hard.
Anchor	12-35	Sand	Shallow, soft; deep, soft to hard.
Bacon's Castle	15-40	Sand and marl	Soft to hard
Cabin Point	16-30	Sand	Soft to hard
Claremont	40-60	Sand and marl	Hard
Dendron	12-26	Shallow, clay; deep, clay and marl.	Shallow, soft; deep, hard.
Elberon	8-25	.....	Fair to good
Hargrave	20	Sand	Soft
Ingenall	50	Marl	Hard, cistern
Ruffins	8-40	Sand and marl	Deep, hard
Savedge	10-24	Clay	Fair to good
Scotland	60-80	Iron crusts and marl.	Limy and irony
Spottsville	10-80	Shallow, sand; deep, marl.	Shallow, soft; deep, hard.
Surry	15-40	Sand, marl	Soft
Wiedman	35-45	Sand and marl	Hard

Conclusions.—Plenty of good water can be had in Surry County by dug, driven, or drilled wells. Artesian waters that will rise 20 to 35 feet above sea level can be had anywhere. Their quality will be found excellent for most purposes, but toward the east side of the county they may not be altogether satisfactory for certain industrial uses.

At Dendron, where the question of obtaining better water than that afforded by shallow wells will demand attention with the growth of the town, plenty of water can be had from the basal Chesapeake sands at 300 feet, or the Pamunkey sands at 550 feet, by 8-inch wells and pumps or air-lifts. Flows are impossible. In the swamp along Blackwater River south of the town, the Pamunkey waters may rise to surface. Flows are impossible at Surry, the elevation of the ground at the Courthouse being about 100 feet. By drilled wells and pumps soft alkaline water can be had at about 400 feet.

In case artesian water is sought for town supply at Claremont, a well or wells near the foot of the bluff will probably be more satisfactory than wells in the center of the town. In the latter situation flows can not be had, the altitude being 90 feet, but flows can probably be had near the river and it will be more economical to locate a pumping station there than to use deep well pumps.

SUSSEX COUNTY.

General description.—Sussex County, formed in 1754 from Surry County, is separated from the latter by Blackwater River. It extends from Blackwater River to Nottoway and Meherrin rivers, and is about 40 miles long from its northeastern to its southwestern corner. The southwestern corner of the county lies west of the Piedmont-Coastal Plain boundary. The two most important towns are Waverly and Wakefield.

The topography varies from slightly rugged in the southwest to undulating in the northeast. The larger portion of the surface is included in the Sunderland terrace. The maximum elevation reported is near Jarratt, 155 feet; the minimum is on the banks of Meherrin River near Emporia, 25 feet. The general slope of the surface is southeast. Coppahaunk Swamp and Warwick Swamp flow northeast to Blackwater River; Joseph's Swamp, Stony Creek, Roaring Creek, Poplar Spring, and Assamoosick Swamp flow south or southeast to the Nottoway.

Geology.—While the Chesapeake (Miocene) clayey sands and marl beds underlie practically all the county as far east as the Atlantic Coast Line Railway they are seldom exposed, owing to the coating of Columbia (Pleistocene) loams and sands. On the west the St. Mary's formation of the Chesapeake overlaps the Potomac beds and rests directly on the crystalline rocks. Its shell or marl beds have been opened by many small pits and dug for fertilizer. Pamunkey (Eocene) beds probably underlie the Chesapeake east of Sussex but are not known to outcrop anywhere in the county. At Bolling's Bridge on Nottoway River is an outcrop of a bed of cobbles and pebbles that has been regarded as a basal bed of the Potomac group, Lower Cretaceous; it may belong to the Chesapeake. From feather edges the Chesapeake and older formations thicken eastward and at Wakefield the base of the Chesapeake is probably 300 feet below the surface, the base of the Pamunkey 50 feet deeper, and the crystalline bed rock not less than 700 feet below. The surficial sands, gravels, and loams belong to the Sunderland, Wicomico, and Talbot formations of the Columbia group.

UNDERGROUND WATERS.

Distribution and quality.—The abundant ground water in the Columbia sands and Chesapeake sands and marls varies in quality from soft to hard, and in places is irony. Artesian waters underlie the eastern half of the county. Little is known of them, but it is safe to say that they are of excellent quality. There are no flowing wells in the county but it is likely that some artesian waters will rise to the level of the swamps along Nottoway River south of Lumberton.

Springs.—There are numerous springs and seeps along the rivers and their tributaries. Nearly all issue from the white sands which mantle the valley slopes and their geologic source can not be determined by inspection. Most are of small flow and many fail in droughts. The springs are little used except for watering stock. The only one in the county of commercial note is the Coppahaunk on Coppahaunk Swamp, about $1\frac{1}{2}$ miles south of Waverly. It has had considerable repute and is now owned by persons who bottle and ship the water. The flow is free, about 25 gallons per minute. The water rises through sand and probably comes from a Chesapeake shell bed; it is iron-bearing and is said to have slight sulphur taste when fresh from the spring. The following analysis is recomputed from one furnished by the company:

Analysis of water of Coppahaunk Spring, Waverly.

(Froehling & Robertson, analysts.)

	Parts per 1,000,000
Total solids	293.
Silica (SiO_2)	23.
Iron (Fe)	0.7
Aluminum (Al)	9.9
Manganese (Mn)	trace
Calcium (Ca)	93.
Magnesium (Mg)	1.5
Strontium (Sr)	0.1
Barium (Ba)	0.15
Zinc (Zn)	faint trace
Sodium (Na)	5.4
Potassium (K)	2.9
Lithium (Li)	0.19
Arsenate radicle (AsO_4)	0.034
Phosphate radicle (PO_4)	0.12
Carbonate radicle (CO_3)	143.
Sulphate radicle (SO_4)	1.6
Iodine (I)	trace
Bromine (Br)	trace
Chlorine (Cl)	11.

Wells.—Dug wells, generally cased with wood, are the main source of supply at most farms, and in many villages. The cost of digging these is low. There are some bored wells and at Waverly and Wakefield many driven wells. No deep drilled wells are reported.

LOCAL SUPPLIES.

At Wakefield there are a few dug wells and over 75 driven wells, the latter from 19 to 22 feet deep. They get soft water in sands underlying loam. A peanut mill gets water from an 80 horsepower tubular boiler from

two dug wells about 15 feet deep. The supply is fairly good for boiler use though it has a tendency to form scale. (See table 7.)

At Waverly, where are large lumber mills, nearly all the water for both boiler and domestic supply is obtained from driven wells, which range in depth from 15 to 35 feet. Dug wells which strike the first water bed at 15 feet sometimes fill to the top and are liable to pollution. The water from the second sand, at 30 to 35 feet, is preferred by those persons who have had wells driven to it, and is certainly less liable to pollution than that from 15 feet. In fact, in 1906, this 35-foot water was as good as need be, as no dug wells had been sunk deep enough to permit direct pollution of the water bed. The yields to pumps are remarkable. One 35-foot well, 2 inches in diameter, is stated to give 30 gallons per minute, while at the plant of the J. D. Gray Lumber Co., 2 wells furnish water enough for 250 horsepower. As a boiler water, though considered hard, it seems satisfactory, forming very little scale. Its quality is indicated by a field assay in table 7.

The expense for a 35-foot well at Waverly is slight. A 2-inch pipe can be driven for about \$5, and the well equipped with a pitcher pump costs about \$10.

Information collected regarding dug wells at various places in the county is summarized as follows:

Details of dug wells in Sussex County.

Location	Depth of well (Feet)	Water bed	Quality of water
Airland	20-60	Clay	Irony
Booker	10-30	Shallow, clay; deep, "black mud."	Soft
Comans Well	15-30	Clay	Fair, good
Hilda	10-50	Sand, marl	Soft and hard
Jarratt	12-30	Gravel	Soft
Lumberton	6-30	Shallow, sand; deep, clay or marl.	Soft and hard
Masons	7-35	.....	Soft
Peanut	15-20	Loam	Soft
Westhope	8-40	Sand and clay	Soft

At Jarratt some wells dug for boiler supply are 16 feet square and 20 feet deep.

WARWICK COUNTY.

General description.—Warwick County, one of the smallest counties in the State, was one of the eight original shires of the colony of Virginia. It lies along the north bank of James River near the end of "the peninsula."

The topography is somewhat diversified though the relief is not great. The northern part of the county lies within the Sunderland terrace which has an elevation of 86 feet at Halstead's Point, in the extreme northern corner. The greater part of the county is included in lower terraces. The lowest plain includes Mulberry Island. The city of Newport News stands on two terraces.

Geology.—Columbia (Pleistocene) sands and loams mantle the surface. On the lower terraces are local lenses of clay that have been worked for brick on Mulberry Island and at Morrison. At Newport News dark bluish mud containing cypress stumps and bluish sand containing marine shells outcrop in the river bluff beneath gray pebbly sands.

Clayey sands and beds of shell marl mostly belonging to the Yorktown formation of the Chesapeake group (Miocene) are exposed in the creek valleys. The total thickness of the Chesapeake at Halsteads Point is about 450 feet, and at Newport News about 550 feet, its base lying 400 to 550 feet below sea level. The Pamunkey (Eocene), Upper Cretaceous, and Potomac (Lower Cretaceous) lie below the Chesapeake. The base of the Pamunkey is about 600 feet below tide at Halsteads Point, and 700 feet below at Newport News. Evidence as to the thickness of the Upper Cretaceous is contradictory. The base of the Potomac lies over 2,000 feet below tide at Newport News.

UNDERGROUND WATERS.

Distribution and quality.—The ground waters in the Columbia and Chesapeake beds show the usual variations in quality; here soft and clear, there hard and irony. Depths to the water table differ considerably, and where it rises to the surface after prolonged rains, as on flat stretches, the quality of the ground water is not considered so good as where the water table lies deeper.

An abundance of artesian water underlies the county but that so far developed is rather highly mineralized, the mineralization increasing toward the southeast. This increased mineralization is due in part to the water-bearing sands growing finer, and as a result yields to wells and heads of flows are least in the wells farthest down the river.

Springs.—There are no springs of especial importance in Warwick County, but a few are still used for household supply. The smaller springs

seep from Columbia sands; the larger flow from shell beds in the York-town formation. The waters of the latter are apt to be hard. Some of the larger springs are so situated that they can be advantageously developed by rams.

Wells.—Dug wells are chiefly used. There are a few drilled wells along James River. Near Newport News there are numerous driven wells and a few at other places in the county.

LOCAL SUPPLIES.

The Newport News Water & Power Co. supplies the city of Newport News with water from a watershed it owns. Practically every one in Newport News uses this water, though on the outskirts of the city are shallow, driven and dug wells which obtain supplies, in some instances of suspicious purity, from Columbia sands. Attempts to get artesian water at Newport News have been mentioned. (See page 97.) The artesian wells in the county are all near James River. There are two on Mulberry Island, one at Mulberry Island post-office, the other at Curtis Point. Both of these wells probably get water from sands in the Chesapeake group at 360 to 380 feet below mean high tide. The owner of the well at the post-office has shipped more or less of the water to Newport News and Norfolk. It is soft, clear and refreshing, and has some local repute for medicinal properties. The accompanying analysis furnished by the owner, but recomputed to standard form, shows the large proportion of bicarbonate of soda characteristic of artesian wells in other parts of the Virginia Coastal Plain.

Analysis of water from well of P. H. Wright, Mulberry Island.

(W. H. Taylor, analyst.)

	Parts per 1,000,000
Silica (SiO_2)	13.0
Iron (Fe)	trace
Calcium (Ca)	4.2
Magnesium (Mg)	1.2
Sodium (Na)	354.0
Potassium (K)	15.0
Lithium (Li)	trace
Bicarbonate radicle (HCO_3)	454.0
Sulphate radicle (SO_4)	44.0
Chlorine (Cl)	273.0

The well at Curtis Point is of interest from its location and the quality of the water. In the latter respect it resembles the well at Mulberry Island post-office, but the water is more mineralized. A complete analysis appears in table 8.

At attempt to get a flow at Menchville on the mainland opposite Curtis Point proved unsuccessful, possibly because of the well being started on too high ground, as the head of the flow at Curtis Point is only about 20 feet above sea level. A well at Lee Hall 406 feet deep reaches a sand having about the same stratigraphic position as that yielding flows on Mulberry Island. The elevation of the well is 42 feet and the water rises within 12 feet of the surface.

Conditions reported from some of the places in Warwick County, where dug or driven wells are the sources of domestic supply, are summarized herewith:

Details of shallow wells in Warwick County.

Location	Depth of well (Feet)	Water bed	Quality of water
Denbigh	25-30	Clay and sand	Soft, hard
Halstead Point	30-50	Sand and marl	Hard and irony in deep wells
Lee Hall	18-25	Sand	Soft
Menchville	10-31	Sand	Soft
Mulberry Island	10-15	Sand	Soft, irony

Conclusions.—The wells already drilled indicate that from the Chesapeake sands under Warwick County, moderate heads, 20 to 30 feet, and fair flows at the northwest end of the county with diminishing yields and increasing mineralization southeastward, may be expected. Slightly higher heads and freer flows can probably be had from deeper sands in the Pamunkey, Upper Cretaceous, or Potomac, but heads over 35 feet above tide are not to be expected, nor is there any reason to expect much improvement in quality with depth. Water much better adapted to ordinary household use than the supplies obtained from some shallow wells at many places can be had west of Curtis Point. Farther east the outlook becomes increasingly dubious. Prospects in the immediate vicinity of Newport News have already been discussed. (See pages 97 to 116.)

WESTMORELAND COUNTY.

General description.—Westmoreland County lies south of Potomac River on the "northern neck." The topography is characterized by high terraces with undulating surfaces sharply cut by creek gorges and comparatively level lower terraces. Some of the creeks flowing to Rappahannock River head within a mile or two of the Potomac. Some of those flowing toward the Potomac empty into tidal inlets or rivers, such as Nomini River and Yeocomico River.

Elevations on the Sunderland terrace range from 160 feet in the vicinity of Bainesville to 110 feet back of Kinsale. Near Bainesville is a small area above the general level of the Sunderland, and there is another near Stratford. These areas may be remnants of the Lafayette terrace. Lower Columbia terraces are traceable along Potomac River. A striking feature of the topography of Westmoreland County are the famous Nomini Cliffs which extend for nearly 10 miles along the Potomac between Popes Creek and Currioman Bay. These cliffs in places are 200 feet high. Along Rappahannock River below Wilmont Landing are conspicuous cliffs, in places over 100 feet high.

Geology.—The loams, cobble beds, sands, and gravels of the Columbia formations outcrop in many road cuts and in the river cliffs. The lower formations of the Chesapeake group (Miocene) are exposed in many places. Over 200 feet of the Calvert are visible in the Nomini Cliffs and the diatomaceous clays of the formation are to be seen in the cliffs on Rappahannock River. The base of the Calvert is near tide level on the western edge of the county, while at the mouth of Yeocomico River at Lynch's Point it is 350 feet below. The greensands, clays, and shell beds of the Aquia and Nanjemoy formations of the Pamunkey (Eocene) have a total thickness of about 250 feet, and the base of the Pamunkey is 300 to 550 feet below river level. Little is definitely known of the thickness and extent of the Upper Cretaceous beds. The Potomac group may be 500 to 1,000 feet thick and the crystalline bed rock probably lies from 1,000 to 1,500 feet below tide.

UNDERGROUND WATERS.

Distribution and quality.—The Columbia formation and the top beds of the Chesapeake group carry ground water within the county limits. Near the edges of the highest terrace the water table is 30 to 60 feet below the surface and fluctuates slightly. On flat stretches of the same plain it may fluctuate 15 to 20 feet and rise to the surface after a wet season. The quality of the water varies from soft to irony or hard. Shallow water in the Chesapeake beds is at many places hard.

Sands in the Chesapeake, Pamunkey, and Potomac groups are known to contain artesian water. As the beds dip east the depths to the sands increase in going down the river. At the west end of the county the Chesapeake beds are little below tide level and do not give flows; east of Mount Holly most wells draw on them. The sands most widely developed are at the base of the Calvert formation. Higher sands supply wells at the east end of the county. The Nanjemoy sands have been reached by relatively few wells east of Colonial Beach. The heads of the flows vary but the waters most developed had heads of 15 to 30 feet above tide. All the waters

sampled from wells reaching Chesapeake or Pamunkey sands were soft and alkaline.

Springs.—Small seeps and springs that feed the creeks flowing to Potomac River are found throughout the county. So numerous are they that as one man expressed it, a spring can be had on any hillside by a little work with a hoe. A few springs, such as those of R. O. Costenbader near Remus, and Wm. Taylor, opposite Kinsale, furnish drinking water or water for household supply; many are so situated that they can be developed to advantage by rams. From no spring is water marketed and none is a resort.

Wells.—On high ground dug wells curbed with wood are the chief source of domestic supply. Some of these wells are poorly located and very liable to pollution. On the high terraces wells are from 20 to 60 feet deep, on the lower terraces they are seldom over 40 feet and the average depth is under 20 feet. There are some bored and some driven wells, and along the river and the tidal courses of the creeks are many drilled wells of small diameter. The cost of these to the owner has averaged between 25 and 40 cents a foot.

LOCAL SUPPLIES.

No town in the Virginia Coastal Plain has benefited more from the development of artesian water than Colonial Beach. The first deep well was drilled in 1887. Before that all persons, and for some years afterward many persons, drank the water obtained by shallow wells 6 to 15 feet deep, and as a rule poorly protected. Typhoid fever obtained a foothold and was in some years epidemic. Since the substitution of artesian for dug wells typhoid has practically disappeared.

Nearly all the artesian wells reach a greensand in the Aquia formation of the Pamunkey, about 200 feet below river level. According to the driller, who sunk many of the wells in town, none of those reaching this sand is over 220 feet deep. The sand is immediately overlain by some 10 feet or so of red or chocolate-colored clay. The sections reported vary, but the following may be taken as an average:

Generalized section at Colonial Beach.

Material	Thickness (Feet)	Depth (Feet)
Soil and sandy loam	8	8
Yellow to buff clay	4	12
Gravel and sand	7	19
Blue marl, black sand, dark clay, shells.....	150	169
White clay	2	171
Red and chocolate-colored clay not over 10 feet thick on beach	10	181
Rather fine green or black sand, water bed.....	20	201

Some wells pass through "rock" 8 to 10 inches thick in the blue marl at 150 feet. Most of the wells are 11½ inches in diameter and were sunk by hand rigs. Prices for drilling have been \$50 to \$75, according to care in placing casing, etc.

The water from the 200-foot wells as it comes from the same horizon varies little in quality. It has a slight sulphur odor and is decidedly alkaline (see field assays, table 9). It is used for all purposes. As a boiler water it has a tendency to foam and pit tubes.

At the ice plant where a well to the 200- to 225-foot sands gave an insufficient supply, a well to a sand in the Potomac group found plenty of good water. The driller reported the following log:

Record of well at Ice Plant, Colonial Beach.

(Authority, Roland Rude, driller.)

Material	Thickness (Feet)	Depth (Feet)
Made land	6	6
Yellow clay	13	19
White clay	2	21
Green marl	39	60
Black earth with sand	140	200
Rocks in coarse brown sand, a little water	100	300
Black earth with large grains of heavy sand	50	350
White clay, with some very soft streaks	50	400
Red clay	15	415
White sand with plenty of water	7	422

The well is 11½ inches in diameter, the flow is 6 gallons per minute at an elevation of 5 feet.

Outside the thickly settled portion of the Beach there are still wells of good flow to the 200-foot sand. One of the best is that of the McGinnis estate at the south end of town, which when dug flowed about 3 gallons per minute at an elevation of 9 feet above high tide.

North of the Beach at Wilkerson's Wharf are two wells, 233 and 235 feet, respectively, flowing 3½ and 1¾ gallons per minute at elevations of 4 and 7 feet above tide water. The wells are said to have struck the Beach flow at 214 feet but found it a mere drip. After going through 10 feet of white sand and "rock," the latter in layers 1 to 10 inches thick, and 20 feet of "red clay," the present flow was struck which rose 40 feet above sea level and gave 5 gallons per minute.

At L. C. Handy's, west of Wilkerson's, is a well that has a measured head of 22 feet, and flows into a tank about 20 feet above mean high tide. An attempt made to get a flow at an elevation of 30 feet above tide was unsuccessful though the well was sunk 471 feet, according to the driller.

In the vicinity of Erica the sands that yield waters to the wells near the head of Nomini River are apparently too fine to give flows, and several wells have gone to sands in the Pamunkey at reported depths of from 300 to 350 feet. One at the post-office, elevation about 20 feet, is said to be 336 feet deep and to have flowed in 1902 when drilled. In 1906 the water stood about 3 feet below surface.

A mile east of Maple Grove and some 3 miles west of Colonial Beach, a well was drilled in 1905, for Floyd Omohundro, on the Wicomico terrace at an elevation of 60 feet. This well found water in white sand, which rose to about 40 feet of surface. The well is cased for only about 40 feet, and, according to Mr. Omohundro, since it was drilled there has been a change in the quality and yield of the water in his dug well, 45 feet deep, about 20 feet distant, indicating that the artesian water finds its way into the dug well.

At or near Kinsale, on Yeocomico River and its inlets, a considerable number of flowing wells have been put down. Those at Kinsale are said to range in depth from 238 to 275 feet, most of them striking a water-bearing sand in the Calvert formation at 245 feet. The heads average about 17 feet above mean high tide, and the flows at an elevation of 6 feet are about 4 gallons per minute through a 1½-inch pipe. The water, which has a slight sulphur odor, is used at canning factories and also for drinking. In a boiler it works fairly well, not pitting the tubes, but having a tendency to foam. At the canning factories it is the custom to blow off some of the water in a boiler, one or two gages, several times a week. The general character of the water is indicated by the field assays in table 8.

North of Kinsale on Sandy Point Farm, the 5,000-acre estate of J. R. Dos Passos, of New York, there are no less than 15 flowing wells. Many of them are at tenants' houses and were intended to furnish pure water for domestic use, the supplies from shallow wells having, it was thought, caused malarial disorders. A marked improvement in the health of those using artesian water is claimed. The following log was furnished by the driller:

General record of wells near Sandy Point.

(Authority, F. H. Jones, driller.)

Material	Thickness (Feet)	Depth (Feet)
Loam	17	17
White sand	8	25
Blue clay (called fullers earth)	150	175
Marl and layers of shells	50	225
Thin layers of rock about 2 feet apart, with sand between.....	5	230
Black sand, water-bearing		230

This water has the general characteristics of the flows at Kinsale as shown by the field assay in table 8.

At Sandy Point farm on the river shore at Lynch Point, is a flowing well but 90 feet deep which may tap a sand in the St. Mary's formation of the Chesapeake. The head of the flow is about 3 feet above high tide. The water decidedly differs from the deeper flows; it contains more iron and lime, as shown by field assay (table 7), and is little used. In a way the well resembles in low head and quality of flow some of the wells in Accomac County.

Near Nomini River there are flowing wells at Mount Holly, Hinnom, Beal's Wharf, McGuire's Wharf, and Erica. Most of them draw on the Calvert sands of the Chesapeake group. The well at Mount Holly is 150 feet deep and flows, at an elevation of 9 feet above tide, about 5 (?) gallons per minute through a 1½-inch pipe. A field assay of the water is given in table 8. Some of the wells on Nomini River tap deeper sands, if reported depths are trustworthy, but the waters are much alike. Most of the wells have cost \$40 each.

At Oak Grove, on the Wicomico terrace, several attempts to get artesian flows have failed, owing to the elevation of the surface, 60 feet. Some wells at Oak Grove, at 25 to 30 feet deep, are poorly situated and continually liable to pollution.

Two miles southeast of Oak Grove an attempt to get a flow at the residence of Andrew Flanner failed because of the elevation, though the well went down 664 feet. Mr. Flanner has a dug well 63 feet deep that gets water in Chesapeake sands.

Data collected regarding dug wells at a number of villages in Westmoreland County is summarized as follows:

Details of dug wells in Westmoreland County.

Location	Depth of wells (Feet)	Water bed	Quality of water
Bainessville	35-60	Sand and clay	Soft to hard
Erica	12-18	Sand and marl	.....
Hague	35-40	Sand and gravel	Soft
Homers	20-45	Sand	Soft
Index	30-45	Sand and gravel	Soft
Kinsale	15-25	Sand and marl	Soft to hard
Leedstown	14-20	Sand	Soft
Machadoc	12-30	Sand	.....
Maplegrove	30-60	Sand	Soft
Meter	15	Sand	Hard
Montross	30-50	Sand	Soft, hard
Oldhams	18-60	Clay	Soft
Potomac Mills	15-30	Sand and marl	Soft to hard
Rollins Fork	30-50	Sand	Soft
Remus	30-80	Sand	Good
Templeman Cross Roads	25-35	Sand	Soft
Tuckerhill	16-60	Sand	Good
White Point	18-20	Clay and sand	Soft
Zacata	15-40	Clay	Deep, hard; shallow, soft.

Conclusions.—The volume of flows obtainable by carefully cased wells from the artesian sands under Westmoreland County, the quality of the water, its superiority to the supplies obtained by many dug wells, and its freedom from disease germs, are reasons for more extensive development of these sands. Flows are not to be expected at points more than 35 feet above sea level, but higher heads than those found in the artesian sands nearest surface can be obtained by deeper drilling.

At Oak Grove, soft water free from disease germs can be had by pumps from wells to the Calvert sands at 250 feet, or the Potomac at 450 feet. The water from the latter will rise to about 25 feet of surface.

At Montross the water from the Pamunkey sands, to be reached at 400 feet, will rise to about 70 feet of the level of the Courthouse. In Kinsale, flows at the elevation of the higher ground in the village are impossible; wells to the Pamunkey sands at 500 feet may rise fully 30 feet above the river.

YORK COUNTY.

General description.—York County, one of the original shires of Virginia, lies along the south side of York River on "the peninsula," of which it covers the larger portion. The surface of the county is diversified by tributaries of York River, the more important creeks being Ware, Scimmins, King and Queen, which cut back into the several Columbia terraces. The greatest elevation of the Sunderland terrace, at the northwestern corner of the county, is about 110 feet.

Geology.—The Columbia formations form the soils over most of the county. No formations older than those of the Chesapeake group are visible. Along York River the St. Mary's and Yorktown formations outcrop, and at Yorktown, the type locality of the latter, and 3 miles up stream the bluffs are full of shells. Firm rock composed almost wholly of ground-up shells makes the base of the bluff at Yorktown. The bottom of the Chesapeake group lies 180 feet below tide water in the northwestern corner of the county, and 550 feet below in the vicinity of Messick. The Pamunkey (Eocene) greensands and clays which underlie the Chesapeake formations are about 100 to 200 feet thick. Their base is approximately 400 to 800 feet below sea level. Upper Cretaceous beds undoubtedly underlie the Pamunkey, but their thickness is undetermined. The base of the Potomac (Lower Cretaceous) group lies possibly 1,200 feet below tide water in the northwestern part of the county and 2,300 feet below in the southeastern. The total thickness of the group in the eastern part of the county is fully 1,300 feet.

UNDERGROUND WATERS.

Distribution and quality.—The Columbia formations all carry more or less ground water, the depth to the water table, the yield to wells, and the quality of the water differ with the location of the wells. Wells on high ground, away from a terrace seep or creek valley, obtain soft water from the Sunderland or Wicomico sands within 20 feet of surface; other wells may go 40 feet to water. On the sands of the lowest terrace, east of Yorktown, wells are only 8 to 15 feet deep. The water is mostly soft but in places is iron-bearing, and under marshy tracts along tidal inlets is brackish. Dug wells on this terrace sometimes fill to the top. Where, near terrace scarps or stream valleys, the sands of the higher terraces are thin or contain little water, dug wells go through them and obtain ground water from the Yorktown or St. Mary's formation. This water is at many places hard or irony.

Artesian waters underlie the whole county. The sands in the Calvert formation of the Chesapeake group, in the Nanjemoy formation of the Pamunkey, and in still lower formations, have been tapped by wells on the north bank of York River, but, according to reported depths of wells, only those in the Chesapeake group have been developed in York County.

The supplies obtained are of good volume, heads range up to 30 feet, and the quality is generally satisfactory, the mineralization being greatest in the wells farthest down stream. A slight sulphur odor and a high proportion of bicarbonate of soda are the prevailing characteristics.

Springs.—Seeps and small springs from Columbia sands feed creeks that flow to York River, but are of little economic importance. Most of the larger springs flow from shell beds in the Chesapeake group; a few are used for household supply, and some of these can be used to better advantage by rams.

Wells.—There are many driven wells, and a few drilled wells less than 100 feet deep, on the low expanses of the Talbot terrace in the southeast end of the county; there are a few deep drilled wells along York River; elsewhere dug wells are used to reach underground waters. The relatively small number of drilled wells is a result of the small amount of low ground on the south bank of the river, most buildings being on high ground.

LOCAL SUPPLIES.

At Yorktown there were in 1906 but 3 dug wells; one on the bluff is 60 feet deep, the two others at lower elevation are 40 and 14 feet deep,

respectively. All three go into shell beds and yield hard water. Cisterns are the usual source of domestic supply. A drilled well on the beach, 750 feet deep, yields 1 gallon per minute through a 1-inch pipe. The water is considered good.

At Messick a drilled well 60 feet deep found a flow of slightly ironv water in sands lying either at the base of the Columbia or the top of the Chesapeake group. Particulars of the wells drilled along York River and its tributary creeks above Yorktown are summarized in table 5. They draw on sands tapped by wells across the river in Gloucester County.

One of the more notable wells is that of A. G. Harwood. This well is 400 feet deep and the flow has a head of over 20 feet.

Conditions reported from a number of places in York County that rely on dug wells are summarized in the following table:

Details of dug wells in York County.

Location	Depth of well (Feet)	Water bed	Quality of water
Grafton	16	Sand and marl	Hard
Grove	20-60	Shallow, sand; deep, marl.	Hard
Messick	8-15	Sand	Soft to brackish
Oaktree	25-50	Sand and marl	Soft to hard

Conclusions.—The artesian water prospects in York County vary from good to poor. In the western part of the county good flows can be obtained from Chesapeake, Pamunkey, and Potomac sands down to 1,000 feet or more below sea level, and the resources are practically inexhaustible. Farther east, as indicated by deep drilling in Warwick County to the south, and in Gloucester County to the north, the Calvert sands probably grow fine or clayey; they yield little water, and this contains a decidedly high proportion of solids in solution.

At Yorktown the same sand that is tapped at Gloucester Point yielded little water and the flows from the sands reached by the 750-foot well on the beach were disappointingly small. Stronger flows may perhaps be had by going deeper, but the water will not be any better. Heads will not be over 30 feet above tide and to raise the water to the top of the bluff pumping will be necessary.

On the low ground that begins 4 miles below Yorktown the same conditions probably prevail as in the east end of Gloucester County. Fair water, that will rise 2 or 3 feet above tide, may be found in the Yorktown

formation by wells 80 to 100 feet deep; but little or no water will be found in the lower half of the Chesapeake, or in the Pamunkey. Deeper drilling will find flows in Upper Cretaceous or Potomac beds, but the water will be highly mineralized and at the wells farthest east decidedly saline. There is no reason to believe that better water will be found below 1,000 feet than above that depth. It probably will not pay to try to develop the sands in the Potomac group anywhere in the low ground below the scarp that runs across the peninsula from Newport News to 4 miles east of Yorktown.

TABULATED WELL DATA.

The following table (5) summarizes the information collected by correspondence and field work in regard to a large number of wells in the Tidewater region of Virginia. The list is very far from being complete, no attempt having been made to procure information regarding every well or even a majority of the wells at places where much drilling has been done, such as Colonial Beach, West Point, and Franklin. The depths, heads, and yields printed are in general correct, but some, because they were given from memory by owners, well drillers and others, are little better than guesses. Where figures reported by different persons varied, the more probable figures were taken. The authority for the items relating to each well is shown by the letters in the fifth column of the table, O standing for owner, D for driller, and M for miscellaneous—some third party—in many instances the local postmaster.

In tables 7, 8, 9, 10, and 11 are assembled available analyses and field assays of water from some of the wells listed in table 5. Information regarding the mineral constituents of the water from some of the springs mentioned is segregated in table 6.

Attention is called to the fact that some of the assays and analyses are more reliable than others, but the writer has not attempted to designate those that he considers the most carefully made. As regards the field assays, which are distinguished by (F) after the name of the analyst in the last column of each of the tables, they were made with the apparatus devised by the U. S. Geological Survey.^a The determinations practicable with this apparatus differ widely in accuracy. The writer's experience is that the determination of chlorine can be made with most precision, and that the accuracy of the determinations of iron, calcium, sulphates, or total hardness may be seriously impaired by substances in solution interfering with the reaction that should normally take place.

^aLeighton, M. O., Field Assay of Water, U. S. Geol. Survey, W. S. Paper 151, 1905, pp. 27-75.

Results of all analyses and field assays are stated in parts per million and in ionic form. Thus, a water containing dilute solutions of bicarbonate of lime, bicarbonate of soda, sulphate of soda, sulphate of potash, and chloride of soda (common salt) has its composition indicated by so many parts per million of calcium (Ca), sodium (Na), potassium (K), bicarbonates (HCO_3), sulphates (SO_4), and chlorides (Cl).

TABLES OF ANALYSES OF WELL AND
SPRING WATERS

TABLE 5—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide.	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
Accomac						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Accomac	near	Benj. T. Melson	I. B. Clark	O	1904	24	50	2	50	15,35	50
Accomac	2 mi. E.	L. L. Tiffany		M	1899	100	2	100			
Belinda	1/2 mi. E.	M. E. Hall	I. B. Clark	O	1902	68	1 1/2				
Belinda	1/2 mi. E.	M. E. Hall	J. W. T. Robertson	O	1899	84	2				
Belinda	Near	Hall & Rose	I. B. Clark	O	1902	68	1 1/4				
Belinda	1/2 mi. S.	J. D. Bull				80		40			
Bellehaven		C. S. Witham & Bros.		M		86	1 1/2				
Bellehaven		D. R. Mister		O		120	1 1/2	120			
Bellehaven		C. F. Chase		M	1901	2	60	1 1/2		6-16	
Bloxom		Guilford Church	W. McK. Taylor	M		105	1 1/2				
Boggs	near	H. Battail	I. B. Clark	O	1906	10	150	1 1/2	150		130
Boggs	near	F. C. Taylor	I. B. Clark	O	1904	8	150	1 1/2	150	75	60
Cashville		E. M. Boggs	J. W. T. Robertson	O	1902	8	101	1 1/2	101		100
Cashville		H. R. Boggs	J. W. T. Robertson	O	1902	6	97	1 1/2	97		97
Cashville		H. R. Boggs & Bro.	J. W. T. Robertson	O	1904	6	90	1 1/2			
Cashville		Broadway Baptist Church	J. W. T. Robertson	M	1904	12	110	1 1/2			110
Cashville		S. Crockett	Bailey East	D		112	112				
Cashville	near	W. S. Finney	J. W. T. Robertson	O	1902	7	100	1 1/2	100		100
Cashville		T. W. Scott	J. W. T. Robertson	O	1902	97	1 1/2	97			
Cashville		T. W. Scott	J. W. T. Robertson	O	1904	87	1 1/2	87			
Cashville		T. W. Scott	J. W. T. Robertson	O	1906	2	90	1 1/2	90		
Chesconnessex		Bailey East	Bailey East	O	1905	1 1/2	137	1 1/2	137	40, 75, 100	
Chesconnessex		F. L. Savage	I. B. Clark	D	1903	5	103	1 1/2			
Chesconnessex		F. Jenkins	J. W. T. Robertson	M	1901	1	90	1 1/2	90		
Chincoteague Is.		United States		1885?	3	135	2				
Chincoteague Is.		James Williams	James Williams		1890	5	70	1 1/2			
Craddockville		Thos. J. Custis	I. B. Clark	O	1902	2 1/2	62	1 1/2	60	12, 22	60
Craddockville		G. B. Mason	J. W. T. Robertson	O	1902	6	60	2	60		20
Craddockville	near	L. J. Melson	J. W. T. Robertson	O	1900	4	140	1 1/2	140		
Craddockville		L. J. Melson	I. B. Clark	D	1904	7 1/2	175	1 1/2	173		140
Davis Wharf		S. J. Bull	J. W. T. Robertson		1902	105	2 1/2				105
Finney	near	Susan A. Finney		M	1899	2	90	1 1/2	90		
Finney		W. F. Rogers	J. W. T. Robertson	O	1901	1 1/2	83	1 1/2	83		83
Finney		Mears	I. B. Clark	D	1906	1 1/2	80	1 1/2			83
Finney		S. F. Rogers									
Fox Island		Wm. Ellinger	J. W. T. Robertson	O	1903	6	76	1 1/2			
Franklin City	near	Wm. B. Powell	F. T. Mumford		1904	60	73	1 1/2	70	36, 38	
Gratons	1/4 mi. N. E.	W. A. Bloxom	F. T. Mumford	O	1904	11	151	1 1/2	151	80	
Gratons		J. W. Weasells	F. T. Mumford	O	1904	10	160	1 1/2	160	85	
Gratons	near	E. D. Groton	F. T. Mumford		1904	10	100	1 1/2	100	75	
Harborton	near	J. W. Adams	J. W. Adams	D	1905	8	149	1 1/2			138
Harborton	near	W. H. B. Custis	J. W. Adams	D	1900	8	144	1 1/2			55
Harborton	near	Allen & Sennen		M	1882	6	148	1 1/2			
Harborton	near	S. K. Martin	I. B. Clark	D	1903	10 1/2	137	1 1/2	137	35, 128	94
Harborton	near	Martin & Mason Co.	J. W. T. Robertson	O	1903	2	140	1 1/2	140	35, 128	100
Harborton		Geo. Moore	J. W. Adams	D	1906	8	174	1 1/2			60
Harborton		W. K. Reed	J. W. Adams	D	1905	8	139	1 1/2	139		55
Harborton		J. W. Walker	J. W. Adams	D	1905	8	145	1 1/2	145		55
Hallwood		Wesley Bloxom	J. W. Adams	D	1904	5	150				
Hallwood		Wm. T. Bloxom	J. W. T. Robertson	D	1906	7	103				
Hallwood	near	James A. Hall	I. B. Clark		1903	10	186	1 1/2	20	110, 150	
Hallwood	near	New York, Philadelphia & Norfolk R. R.				10	35-60				
Hallwood		James W. Tailor			1902	10	140	1 1/2			
Hopkins		John Barnes	J. W. T. Robertson			125	1 1/2	125			

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
Gray sand.....	Columbia.....	Ft. +17	Gal.	5	58	Soft	Domestic and stock
	Columbia (?).....	+10	1¼		59		Drinking and stock
Sand and shells.....	Columbia.....	+10		2		Hard, brackish, irony.....	Washing oysters
	Columbia (?).....	+2					Abandoned
Sand and shells.....	Columbia.....	0				Hard, brackish, irony.....	Washing oysters
	Columbia.....	flows				Soft	Domestic
	Columbia.....						Domestic
	Chesapeake (?).....	+5					Domestic and canning factory
Sand.....	Columbia.....	+4					Drinking
	Chesapeake (?).....						Drinking
	Chesapeake (?).....	+8				Soft	Domestic
Sand.....	Chesapeake (?).....	+8	5			Soft	Domestic
	Chesapeake (?).....	+5		8	60	Slightly sulphur and iron-bearing	Domestic
	Chesapeake (?).....	+4		8		Slightly sulphur and iron-bearing	Domestic and stock
	Columbia (?).....			10	59	Slightly sulphur and iron-bearing	Stock
	Chesapeake (?).....	+1					Domestic
	Chesapeake (?).....	+4		8	60	Slightly sulphur and iron-bearing	Domestic
Sand.....	Chesapeake (?).....	+2	¼-1				Domestic
	Columbia (?).....	+3	2				Domestic
	Columbia (?).....						Domestic
	Chesapeake.....	0				Irony	Domestic and stock
	Chesapeake.....						Domestic
	Chesapeake.....	+2	1				Domestic
	Chesapeake (?).....						No flow, abandoned
	Columbia.....						No flow, abandoned
Gravel.....	Columbia.....	+5	3				Domestic and stock
	Columbia.....	+1½	3				Domestic and stock
Shelly rock.....	Chesapeake (?).....	+6	1			Soft	Domestic and stock
	Chesapeake (?).....	+8?					Domestic and stock
Sand.....	Chesapeake (?).....						
	Columbia (?).....		6		59	Slightly sulphur-bearing	Domestic and stock
	Columbia (?).....	+3	4		60	Slightly sulphur-bearing	Domestic and stock
Gravel.....	Columbia (?).....	+2	4				Domestic and stock
Gravel.....	Columbia (?).....			5		Hard, salt and iron-bearing	Washing oysters
Sand and gravel.....	Columbia.....	0					Domestic
Sand and shells.....	Chesapeake (?).....			15		Soft	Domestic and stock
Rock at 85.....	Columbia (?).....	+5				Soft	Domestic and stock
Sand and shells.....	Columbia (?).....	+6		15		Soft	Domestic and stock
Sand.....	Chesapeake (?).....	+8					Domestic
Sand.....	Chesapeake (?).....	+8					Domestic
	Chesapeake (?).....	+8	4-5		62		Boiler
Gravel.....	Chesapeake (?).....	+12	1			Slightly sulphur-bearing	Domestic and stock
Gravel.....	Chesapeake (?).....	+8	5			Slightly sulphur-bearing	Domestic
	Chesapeake (?).....	+8½					Domestic
	Chesapeake (?).....	+8½					Domestic
	Chesapeake (?).....						Domestic
Shells.....	Chesapeake (?).....	+1		15			Domestic and stock
Shells.....	Chesapeake (?).....	+3½		15			Household
Gravel.....	Chesapeake (?).....					Irony	Not used
	Columbia.....						Locomotives
	Chesapeake (?).....					Irony	Not used
Rock at 63 ft.....	Chesapeake (?).....	flows				Soft	Domestic and stock

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
ACCOMAC—Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Hopkins		Oliver Barnes	J. W. T. Robertson	O	1897	108	2	119½	2		70
Hopkins		J. S. Gordy	J. W. T. Robertson	O	1902	119½	2	119½	2	60	116
Hopkins	½ mi. S.E.	A. J. Lewis and W. J. Russell	J. W. T. Robertson	O	1904	4	64	1½	64	15	48
Hopkins		Frank Lewis	J. W. T. Robertson	D	1903	2½	175	1½	170	115-170	120
Hopkins		H. A. Lewis	W. McK. Taylor	O	1901	1	95	1½	95		75
Justisville	near	J. R. Ewell	W. McK. Taylor	M		130		1½			
Justisville		J. T. Willett	W. McK. Taylor	O	1906	68		1½	65		65
Leemont	2 mi. S.E.	J. H. Hopkins	J. W. T. Robertson	O	1897	5	100	1½	100		
Leemont		H. A. Lewis	W. McK. Taylor	O	1899	8	122	2	122		
Locustville		G. L. Dougherty	I. B. Clark	D	1905	6	104	1½	104		
Locustville		B. T. Gunter	J. W. T. Robertson	O	1899	6	140	2	122		122
Mappsville		J. W. Tailor	I. B. Clark	D	1904	40	70	1½	70	16, 32	
Marsh Market	near	Jas. A. Hall (Two wells)	I. B. Clark	D	1904	55-72		1½			
Marsh Market	near	Jas. A. Hall (Two wells)	J. W. T. Robertson	O	1906	5	92	2			
Mearsville	2 mi. N.W.	J. R. Hart	W. McK. Taylor	M	1901	3	85	2	85	25, 40	
Mearsville		S. Rue	J. W. T. Robertson	D	1906	6	150	2			
Mearsville		W. J. Somers	I. B. Clark	D	1904	6½	117	1½	117	80	100
Mandua		Richard Cutter	J. W. Adams	D	1906	4	82	1½			80
Mandua		H. Guy	J. W. T. Robertson	D	1905	2	80	2			60
Mandua		John B. Henderson	O	1902	8	153	1½	153			140
Mandua		Dr. A. T. L. Kusian	J. W. T. Robertson	O	1902	2	74	2	70	8	70
Mandua		John O. Stevens	J. W. Adams	D	1906		140	1½	140	92	100
New Church	near	J. E. Johnson	I. B. Clark	O	1905	24	125	2	125	35, 40, 82	125
Onancock	near	Town	C. S. York & F. A. Merrill	D	1895	8	16-50	2½	50		
Onancock	near	Town	B. T. Parker	M	1890	10	350				
Onancock	near	Town	J. H. K. Shanahan	M	1894	10	486		140	140	
Onancock	near	H. L. Crockett	J. W. T. Robertson	O	1899	2½	109	1½	104	94	
Onancock	near	W. B. Pitts	J. W. T. Robertson	O	1900	4	130	2			
Onancock	near	M. L. Hurst	J. W. T. Robertson	O	1900	3	36	1½	35	9	20
Onley	near	Joseph Bull	J. W. T. Robertson	O	1905	15	51				
Onley	near	J. W. Rodgers	I. B. Clark	D	1905	10	53	1½	53	10, 25	
Parksley	3 mi. W.	W. McK. Taylor	W. McK. Taylor	O	1904	6½	135	1½	135	10, 30, 60	135
Pungoteague		S. W. Ames	I. B. Clark	O	1903	18	210	1½	204	20, 30, 55	208
Pungoteague	1 mi. N.	T. J. Custis	J. W. T. Robertson	O	1902		140	1½	140		140
Pungoteague		S. D. Taylor	J. W. T. Robertson	O	1904	20	110	1½	63		63
Pungoteague		G. B. Mason	J. W. T. Robertson	O	1899		60	2	60	10	
Pungoteague		J. S. Waterfield	J. W. T. Robertson	O	1902	4½	158	1½	158	150	158
Pungoteague		J. S. Waterfield	J. W. T. Robertson	O	1902		140	1½			
Quinby	¾ mi. W.	Machipongo Bridge Co.	J. W. T. Robertson	O	1904	5	87	1½	87	16, 32	
Sanford	near	Frank McKay	J. W. T. Robertson	O	1898	5	76	2			
Sanford		J. J. Furniss				82		2½			
Saxis	near	J. T. Weaver	I. B. Clark	O	1904	4	112	1½	110	73	112
Sanford		Baltimore, Chesapeake & Atlantic Steamboat Company	I. B. Clark	D	1903	4	95	1½			
Tangier Island		J. J. Daly	J. W. T. Robertson	D	1905	3	250	2	141	8	169

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Sand and rock at 90 ft.	Chesapeake (?)	flows	2				Domestic and stock
Gravel	Chesapeake (?)	+1½		25		Soft	Domestic and stock
	Columbia						Domestic and stock
	Chesapeake (?)	+4	2			Sulphur	Domestic and stock
	Columbia	+2	½			Soft	Domestic and stock
	Chesapeake (?)			5			Domestic and stock
Rock at 90 ft. gravel	Chesapeake (?)	+5	2½			Soft, slightly sulphur and iron-bearing	Domestic and stock
Sand	Chesapeake (?)	+6½				Slight sulphur	Domestic
	Chesapeake (?)	+7	1½				Domestic
Sand	Chesapeake (?)	+3½		12			Domestic
Sand	Columbia	+5					Domestic and stock
	Columbia	+5					Domestic and stock
	Columbia	+4		5			Boiler
Rock at 40 ft.							Household and stock
Sand	Columbia	+1½		8		Soft, irony	stock
	Columbia (?)						
Sand	Columbia	+8	1½				Household and stock
	Columbia	+8	1½				Domestic and stock
	Columbia	+2½					
Rock	Chesapeake (?)	+7		5	58		Domestic and stock
	Columbia	+4	1¾		59	Soft, slightly iron-bearing	Drinking and stock
	Columbia (?)						Domestic and stock
	Columbia (?)	+15		5			Domestic
Sand	Columbia					Hard	Town supply
	Chesapeake						No flow, abandoned
	Chesapeake			5		Sulphur-bearing	No water below 140 feet, abandoned
Sand	Columbia	+3	1				
Sand	Columbia		4			Soft	Domestic and stock
	Columbia	+5	2				Domestic and stock
	Columbia			5			Domestic
Sand	Columbia	+8				Soft	Domestic and stock
	Columbia	+7				Soft	Domestic and stock
	Chesapeake (?)	+8			59		Domestic and stock
	Columbia (?)						Domestic and stock
	Columbia	+10		6	60		Domestic and stock
	Columbia	flows	8				Domestic and stock
Sand and gravel	Chesapeake (?)		18(?)				Domestic and stock
	Columbia (?)						Domestic and stock
Sand	Columbia	+7	1½	25		Irony	Domestic
Sand and shells	Columbia	±0					Domestic and stock
	Columbia			5			Domestic and stock
Sand and gravel	Columbia	±0		5		Hard	Domestic and stock
	Columbia	±0					
Fine sand	Chesapeake (?)	±0		5		Salty	No flow, abandoned

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
						Ft.	Ft.	In.	Ft.	Ft.	Ft.
ALEXANDRIA											
Addison		Standard Brick Co.			1895	140					
Addison		New Washington Pressed Brick Co.		O	1898	131					
Alexandria		Southern Railway				370±					
Alexandria		C. M. Adams		O	1898	200	68	48	64		
Alexandria		Alexandria Fertilizer and Chemical Co.	R. L. Thomas	O	1906	10	445	8-6	225	350	
Alexandria		Belle Pre Bottle Co.		O	1907	40	185	6	175		
Alexandria		People's Ice Co.		O	1894	82	401	8-6			
Alexandria		Robert Portner Brewing Co.	W. C. Miller	O	1888	38	430	8	410	61	370
Alexandria		Robert Portner Brewing Co.		O	1902	35	370				
Alexandria				O	1903	38	392	8	370	61	
Alexandria		Washington, Alexandria & Mount Vernon Ry.	Washington Well Drilling Co.	M	1904	8	135	6	60		
		G. N. Saegmuller	W. C. Miller	D			555		80		
Ballston		Livingston Heights Syndicate					160	6	160	100	
Ballston		Admiral Weaver		O		300	60	24	50		
Fostoria		A. M. Lathrop	W. C. Miller	D		172					
Weddebourn		R. W. Walter		O		480	130	6	126	30	
CAROLINE											
Etta		C. M. Harris	C. M. Gouldman		1905	16	175	1½	173		12
Mossneck		A. B. Lewis	Geo. Heflin	D		30	169	2	167	100	167
Port Royal		J. D. Farish	C. M. Gouldman	O	1905	35	243	2			
Port Royal		C. M. Gouldman	C. M. Gouldman	M	1905	23	200	1½	200	175	40
Port Royal		Mrs. Eliza T. Pratt		M		25	200?	2	200?		
Port Royal		Town of Port Royal	Hammer & Hall	M	1905	4	235	1½	235		
CHARLES CITY											
Roxbury	near	T. L. Walker	Sydnor Pump & Well Co.	O	1902	40	280	2-1	280	70	80
Shirley	near	H. S. Saunders	H. E. Shimp	D	1908		355	2			
Sturgeon Point		J. J. Truax	Sherman Jones	O	1895	50	60	72	40		
Westover	1¼mi.E.	Wm. M. Ramsay	Sydnor Pump & Well Co.	O	1901	15	139	10	134	139	
Willcox Wharf		E. A. Saunders, Jr., and Son (6 wells)					168-		168-		
DINWIDDIE											
Petersburg	¼mi.E.	J. B. Worth Co.	A. P. Jerguson	O	1907	2-24	184	2	184		
				D	1892	5	600	8			
ELIZABETH CITY											
Fort Monroe	near	Chamberlain Hotel	Thos. B. Harper	O		4	945	4			
Fort Monroe	near	United States		M		3	907				
Fort Monroe	near	United States		M	1896	3	2,254	15-6		many	2250
North End Point			R. H. Milligan	D	1896	4	1,035	3			
North End Point			J. S. Darling	M	1887	2	1,172	6(?)			

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

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TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
ESSEX						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Bowlers Wharf..	near	Claybrook & Neale	L. Rude	O	1898	5	165	1½	165		16
Bowlers Wharf..	near	Packing Co.	Garrett & Hunt.....	O	1903	5	167	2	167	130	151
Bowlers Wharf..	near	Garrett & Hunt.....	H. L. Skimp.....	O	1896	5	185	1½		130	
Bowlers Wharf..	near	Garrett & Hunt.....	Garrett & Hunt.....	M		8	182	1½			
Bowlers Wharf..	near	C. P. Garrett.....	J. H. Taylor.....	O	1902	10	185	1½	185	170	
Bowlers Wharf..	½mi. S.	I. W. Hunt.....	I. W. Hunt.....	O	1898	19	182	1½			
Blowers Wharf..	1 mi. N.	Frank Hutchinson.....	J. H. Taylor.....	O	1903	4	172	1½	170		160
Blowers Wharf..	1 mi. N.	R. C. Kaighn.....	J. H. Taylor.....	O	1902	4	168	1½	165		163
Bowlers Wharf..	near	R. G. Neal.....	W. S. Johnson.....	O	1888	9	130	1½			
Bowlers Wharf..	½mi. S.	A. D. Pitts.....	J. H. Taylor.....	M	1905		240	1½			192
Bowlers Wharf..	near	Wm. J. Rice.....	W. S. Johnson.....	O	1888	7	260	1½			
Butylo	2mi. N.W.	I. W. Hunt.....	I. W. Hunt.....	O	1898	5	221	1½			80
Caret		J. P. Taliaferro.....	Hammell & Hale.....	M	1903	30	300	1½	290		
Center Cross ..	2mi. S. E.	C. F. Kriete.....	Lyle & Rude.....	O	1891	80?	350	1½			300
Center Cross ..	2mi. S. E.	C. F. Kriete.....	W. S. Johnson.....	O	1895	4	190	1½			180
Center Cross ..	2mi. S. E.	C. F. Kriete.....	L. Rude	O	1903	6	195	1½			190
Champlain		Joseph Baker.....			1903	33	75	1			
Chance		J. H. C. Beverly.....	L. Rude	O	1898	40	380	2	380	250	
Chance		J. H. C. Beverly.....	L. Rude	M		20	260				
Chance		Mrs. M. S. Sale.....	L. Rude	O	1897	30	180	2	180	none	
Dunnsville		J. E. Kriete.....	Geo. Beazeley	O	1888	7	300	1½			188
Dunnsville		J. E. Kriete.....	Chas. Ramsam.....	O	1903	100	60	¾			
Loretto		H. L. Baylor.....	L. Rude	M	1888	-7	160				
Loretto		W. C. Dickinson.....	L. Rude	O	1900	38	198	1½	198		
Tappahannock ..	near	G. N. Anderson.....		M		18	274	1½			
Tappahannock ..	near	T. E. Blakey.....	O. D. Hale.....	O	1906	19	272	1½			65
Tappahannock ..	near	Wm. V. A. Andrews...	Hammell & Hale.....	M	1902	20	270	1½			
Tappahannock ..	near	John Bradley.....	H. E. Shimp.....	M	1902	10	278	1½			
Tappahannock ..	¼mi. E.	B. B. Brochenborough..	Geo. Beazeley.....	O	1901	18	272	3-2	272		272
Tappahannock ..	1mi. N.W.	B. B. Brochenborough..	Hammell & Hale.....	O	1905	27	273	1½	270		
Tappahannock ..	1mi. N.W.	B. B. Brochenborough..	Hammell & Hale.....	O		15	270				
Tappahannock ..	near	R. T. Cauthorn.....	W. J. Reamey.....	O	1895	18	275	1½			275
Tappahannock ..	near	G. F. Croxton.....	Hammell & Hale.....	O	1904	20	268	¾			268
Tappahannock ..	near	G. W. Daingerfield.....	O. D. Hale.....	O	1906	21	275	1½	2		65
Tappahannock ..	¼mi. E.	Donaldson & Schultz...	Hammell & Hale.....	M	1900	4	256	1½	256	125	60
Tappahannock ..	near	J. W. Faulconer.....	Hammell & Hale.....	O	1903	15	275	¾	275	150	275
Tappahannock ..		J. H. Henley.....	Hammell & Hale.....	O	1898	16	275	1½	275		275
Tappahannock ..	near	T. C. McDaniel.....		O	1903	17	282	1½	278		278
Tappahannock ..	near	L. E. Munford Banking Co.	Hammell & Hale.....	O	1904	18	275	1½	275	150	
Tappahannock ..	2mi. W.	D. Passagaluppi	H. E. Shimp.....	O	1903	8	275	1½			
Tappahannock ..		W. B. Robinson.....	Hammell & Hale.....	O	1904		277	2	277	275	
Tappahannock ..	near	G. R. Scott.....				18	275	1½			

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
Sand	Calvert.	Ft. +12	Gal. 49	Gal.	°F. 61½	Soft	Canning factory
Sand	Calvert.	+15	30		63	Soft	Drinking and washing oysters
	Calvert.	+15				Soft	Not used
	Calvert.		5			Soft	
	Calvert.	+15	17				Household
	Calvert.	+19	2				
	Calvert.	+10	7½		61½		Household and stock
	Calvert.	+10	3				Household and stock
	Calvert.		¾				Household and stock
	Pamunkey	+14	6		61¼		Household
	Pamunkey	+12	7		61		Household
	Calvert.	+15	20				Household
	Pamunkey	+31	½			Soft	Drinking
		+30					Not used, no flow
	Calvert.	+12	6		61	Soft	Stock
	Calvert.	+30	32		62	Soft	Canning factory
	Calvert.					Soft	
White sand	Potomac	+43	2			Soft	Domestic
	Pamunkey						
White sand	Pamunkey	+35	2½			Soft, iron and sulphur	Domestic
Sand	Pamunkey		16			Soft	Stock
	Calvert (?)						
	Pamunkey		22				
	Pamunkey		5				Household
Sand	Pamunkey		½		60		Household
Sand	Pamunkey	+30	3		61	Soft	Domestic and public
Sand	Pamunkey		3			Soft	Household
Sand	Pamunkey						Household and stock
	Pamunkey	+31	2	2	62	Soft	Domestic
	Pamunkey	+35	2½			Soft	Domestic
	Pamunkey					Soft	Stock
	Pamunkey	+31	2		61½	Soft	Domestic
Sand	Pamunkey	+29	1½			Soft	Domestic and stock
Sand	Pamunkey	+25	1¾		61		
Sand	Pamunkey	+20	12-5½		62½		Pickle house
Sand	Pamunkey	+18	2			Soft	Household and stock
Sand	Pamunkey	+16	1			Soft	Hotel
Sand	Pamunkey	+20	1¾		61	Soft	Household
Sand	Pamunkey	20					Domestic and stock
Sand	Pamunkey						Domestic and stock
Fine sand	Pamunkey	+20	1-3			Soft	Domestic and stock
Sand	Pamunkey						Canning factory and domestic

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
ESSEX—Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Tappahannock ..	near	H. Southworth	Hammell & Hale.....	O	1903	19	275	1½	.....	.....	.....
Tappahannock ..	near	R. C. Phillips & Co.....	Geo. Beazeley	O	1892	15	275	1½	.....	.....	100
Tappahannock ..	near	Mrs. C. N. Temple.....	Hammell & Hale.....	O	1904	.....	177	3	.....	70, 112	.....
Tappahannock ..	near	E. N. Ware.....	H. E. Shimp.....	O	1898	18	280	1½	.....	.....	.....
Tappahannock ..	near	T. R. B. Wright.....	Hammell & Hale.....	O	1904	18	277	1½	.....	.....	.....
Ware's Wharf.....	1mi.N.W.	R. W. Eubank.....	Wm. S. Johnson.....	O	1888	2	190	1½	190	.....	.....
Ware's Wharf.....	near	H. H. Ware.....	L. Rude.....	O	1899	5	180	1½	170	.....	.....
Ware's Wharf.....	near	R. L. Ware Estate.....	Wm. S. Johnson.....	O	1890	+3	205	1½	185	140	.....
Ware's Wharf.....	¾mi.N.W.	R. L. Ware, Jr.....	L. Rude.....	O	1899	12	180	1½	170	100	.....
Ware's Wharf.....	near	W. L. Ware.....	Geo. C. Taylor.....	M	1895	14	170	1½	165	.....	80
FAIRFAX											
Accotink		C. Lukens.....	—Bushong	M	1887	50	75	5	69	50	18
Accotink		J. P. H. Mason.....	.....	O	1866	180	91	5½	88	45	.....
Clifton Station ..		W. H. Edwards .....	.....	O	1895	.....	.....	.....	100	.....	.....
Gunston .....		.....	L. W. Shepard.....	D	.....	.....	560	.....	264	.....	.....
Falls Church		Henry Birge	—Baker	M	1897	.....	80	6	.....	.....	.....
Fort Hunt .....		.....	J. C. Miller.....	O	1891	30	165	6	.....	.....	.....
Fort Hunt		United States	J. C. Miller.....	D	1899	40	212	8	202	.....	.....
Mount Vernon.....		Mount Vernon Co.	J. H. K. Shannahan	O	.....	4	525	6	340	525	.....
Riverside		Riverside Brick Co.....	.....	O	.....	.....	125	6	.....	.....	.....
Woodbridge .....		.....	Sydnor Pump & Well Co.	D	.....	.....	600	6	150	.....	.....
GLOUCESTER											
Achilles	near	B. A. Rowe.....	.....	O	1903	6	50	2	.....	.....	.....
Achilles	near	B. A. Rowe.....	H. E. Shimp.....	O	1903	6	615	2	450	600	268
Achilles	near	Union Church	H. E. Shimp.....	D	1905	5	450	2	400	.....	400
Allmondsville ..	near	W. W. Allmond.....	J. V. Bray.....	O	1888	6	270	1½	270	150	.....
Allmondsville ..	near	W. W. Allmond.....	H. E. Shimp.....	D	1907	20	400(?)	2-1	400	200	400
Bridges	3 mi. W.	G. E. Brown.....	.....	.....	.....	.....	.....	.....	585?	.....	.....
Bridges	3 mi.S.W.	James Brown	H. E. Shimp.....	D	1904	5	610	2-1	535	.....	.....
Bridges	2 mi. S.	Chas. Catlett	H. E. Shimp.....	O	1903	3	65	1½	.....	.....	.....
Bridges	2 mi. S.	Chas. Catlett	H. E. Shimp.....	O	1903	3	128	1½	.....	.....	.....
Bridges	2 mi. S.	Chas. Catlett	H. E. Shimp.....	O	1903	3	440	2-1	.....	.....	.....
Bridges	3 mi.S.W.	L. M. Kemp.....	H. E. Shimp.....	D	1905	0	510	1½	500	300	.....
Bridges .....	.....	Joshua Minor .....	.....	.....	1904	.....	550	.....	.....	.....	.....
Bridges	2 mi.S.W.	Dr. Oliver	H. E. Shimp.....	D	1904	.....	365	2	.....	.....	.....
Cappahosic	½ mi. E.	Sidney Monsell.....	H. E. Shimp.....	O	1904	33	416	1½	416	375	289
Claybank	at	L. M. Newcomb.....	H. E. Shimp & S. H. Fetterhoff.....	O	1905	6	367	1½	365	none	.....
Freeport	near	E. C. Farinholt.....	H. E. Shimp.....	O	1901	2	330	1½	330	.....	16
Freeport	near	R. H. Farinholt.....	H. E. Shimp.....	O	1901	10	338	1½	330	.....	330
Glass .....	.....	L. Hall	H. E. Shimp.....	D	1904	.....	615	2-1	.....	.....	.....
Gloucester	near	W. E. Carr	Geo. Hughes.....	O	1885	70	350+	1½	350?	.....	.....
Gloucester	near	W. E. Carr .....	.....	O	1893	70	180	1½	59	.....	.....

TABLE 5 (Continued).—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
Sand	Pamunkey	Ft.	Gal.	Gal.	°F.		
Sand	Pamunkey	+29	1¾		61½	Soft	Domestic
Sand	Pamunkey	+10	1½			Soft	Household and stock
	Pamunkey						Domestic
	Pamunkey		3		62		Domestic
Porous rock	Calvert	+5			61	Soft	Domestic and stock
	Calvert	+14	5½		61½	Soft	Domestic
Black sand	Calvert	+14	2-1		61	Soft	Domestic and stock
	Calvert	+14			61½	Soft	Domestic
Rock	Calvert	+16	½		61½		Domestic
Gravel		+40		16	56(?)	Hard	Stock and drinking
Blue clay		+92				Soft	Domestic and stock
Soft slate		-0				Soft	Domestic and stock
							Domestic
White sand	Patuxent	+23		10		Soft	Domestic, stock
Sand	Patuxent	+1		53			Supplies fort
		+1		30			Drinking
	Columbia	+0		10		Soft	Boiler
Sand	Upper Cretaceous	+16	1½		61½	Slightly saline, sulphur	Domestic
Rock	Pamunkey (?)	+10	¼		60	Slightly saline, sulphur	Drinking
Black sand	Calvert	+15	3		63	Soft, sulphur	Drinking
Rock	Pamunkey		2½			Soft	
							Washing oysters, medicinal
							Little water below 60 ft. Not used
	St. Marys	+1½				Soft	Drinking
	St. Marys						
	Calvert					Soft, sulphur	Little used
	Pamunkey	+32					
	Pamunkey				65(?)		
	Calvert (?)	+39					
Fine, dark green rock	Pamunkey	+42	5		65	Soft	Domestic, stock, boiler
	Calvert	+20	1½				Household and stock
	Calvert	+16	2		63		Household and stock
	Calvert		½		63		Household and stock
	Upper Cretaceous						
Black sand		+40					No flow, abandoned
		+40?					No flow, abandoned

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
GLOUCESTER— Cont.											
Gloucester Point	near	Chesapeake S. S. Co., Gloucester County.....	H. E. Shimp.....	D	1903	Ft. 6	Ft. 694	In. 2½ -1	Ft. 690	none	Ft. 180 694
New Upton.....		R. J. Bristow.....	H. E. Shimp.....	O	1901	8	415	¾	415	8-42 235	....
Pinetta.....		E. H. Scanlan.....			1903		215 350	1½	350		
Pinetta.....		Joseph Bryant.....	Sydnor Pump & Well Co.	O	1905	6	1,020	8			
Selden.....	S. W.	Joseph Bryant.....			1900	7	110	6			
Selden.....		Joseph Bryant.....	D. E. Miller and H. E. Shimp.....	D	1905	7	981	6-2	850		981
Selden.....	S. W.	Alfred W. Withers.....	Sydnor Pump & Well Co.	O	1901	6	716	6-4	716		
Sassafras.....	3 mi. S.	B. T. Weaver.....	H. E. Shimp.....	O	1904	4	336	1½	330		
Severn.....	near	J. M. Shackelford.....	W. D. Diggs.....	O	1902	5	610	2	585	610 13 33 160 196	575
Signpine.....	3mi. S.W.	R. C. Coleman.....		O	1886	3½	211	1½	211 180		....
Signpine.....	2 mi. N.	E. H. Scanlan.....	H. E. Shimp.....	O	1903	25	350	2			
Signpine.....	¾ mi. E.	Peter Van Name.....	—Thompson.....	O		5	180	2			
Wareneck.....	2 mi. E.	W. A. Jones.....		M		8	300	1¼			
GREENESVILLE											
Emporia.....		Town.....	Sydnor Pump & Well Co.	M	1906		600	8	470	62 370	28
HANOVER											
Ashland.....	¼ N.	Randolph-Macon College.....		O			140	2			
Ashland.....	¾ N.	Randolph-Macon College.....		O			100	4			
Ashland.....		G. W. M. Taylor..... (Henry Clay Inn)	Sydnor Pump & Well Co.	M	1906		365	8			
Ashland.....		Ashland G. S. & W. Co., Richmond, Fredericksburg & Potomac R. R.....					374 250 327	10			
Doswell.....	near							6			
HENRICO											
Catman.....		Curles Neck Farm.....	F. M. Gould.....		1900	30	926	8		32 150	311
ISLE OF WIGHT											
Benns Church.....		Heath.....					250				
Ivor.....		Shaw Lumber Co.....		O	1907	60	190	6	185		
Shoal Bay.....	3 mi. E.	J. A. Morgart.....	J. P. Ginder.....	O	1900	32	383	2	383	none	383
Shoal Bay.....	3 mi. E.	J. P. Tower.....	W. Wilson.....	M	1907	32	380	1½			200
Shoal Bay.....	½ mi. N.	W. D. Turner.....		M	1906	18	226	2½	220	none	200
Smithfield.....		Smithfield Mineral Water Co.					300				
Zuni.....	near S.	J. M. Darden.....	J. T. Moore.....	O	1895	25	150+	2			
Zuni.....	near	Town of Zuni.....	J. T. Moore.....	D	1895		162	2			
Zuni.....	5 mi. E.	Mt. Carmel Christian Ch.	J. T. Moore.....	D		35(?)	190	2			

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
"White rock"...	Upper cretaceous	Ft. +20	Gal. 2	Gal.	°F. 64+	Soft, sulphur	Drinking, household, etc.
Below rock.....	Calvert.....	+16	1/4	.....	.....	Soft	Domestic and stock
.....	Calvert (?).....	+4	.....	.....	.....	.....	.....
.....	Pamunkey .....	.....	.....	.....	.....	.....	.....
.....	St. Marys.....	+8 1/2	.....	10	.....	Hard	No flow, abandoned
.....	Upper Cretaceous	+5	1/2	.....	.....	Saline, sulphur	Drinking
Sand	Upper Cretaceous	+32	52	.....	70	Saline, sulphur, irony.....	Washing, bathing
Dark green sand	Pamunkey	+20	1 1/2	40	.....	Soft	Domestic and stock
Rock	Pamunkey (?)...	+16	1/2	.....	65	Soft	Drinking
Rock at 196 ft.	.....	.....	.....	.....	.....	.....	.....
Sand	Calvert.....	+8	1	.....	.....	Soft, sulphur	Household and stock
Porous rock.....	Pamunkey	+30	1 1/2	.....	.....	Soft	Domestic
.....	Calvert.....	+15	1/2	.....	.....	Soft, sulphur	Household
.....	Calvert.....	.....	.....	.....	.....	.....	Stock
Granite.....	.....	+20	.....	100	.....	Irony	Abandoned
Sandstone.....	Newark.....	.....	.....	.....	.....	.....	Abandoned
Sandstone.....	Newark.....	.....	.....	.....	.....	.....	Not used
.....	Newark.....	.....	.....	.....	.....	.....	Hotel supply
.....	.....	.....	.....	45	.....	.....	Public supply
.....	.....	.....	.....	85	.....	.....	.....
.....	Newark.....	+30?	.....	.....	.....	.....	Drilled for locomotive supply; abandoned
Granite.....	.....	+4	.....	100	62	Soft	Domestic and stock
.....	St. Marys.....	.....	.....	.....	.....	.....	.....
.....	St. Marys (?).....	.....	.....	.....	.....	.....	Domestic and boiler
Black and white sand.....	Calvert.....	+36	1/10	.....	58	Soft, alkaline	Hotel, medicinal
Black and white sand.....	Calvert.....	.....	.....	.....	.....	.....	.....
Black and white sand.....	St. Marys.....	+30	1/10	.....	.....	Alkaline	Drinking, medicinal
.....	St. Marys.....	flows	.....	.....	.....	Soft, alkaline	Drinking, medicinal
.....	St. Marys.....	32(?)	2	.....	.....	Soft	Drinking
.....	St. Marys.....	.....	1	.....	.....	Soft	Domestic and stock
.....	St. Marys.....	.....	1 1/2	.....	.....	.....	Drinking

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
JAMES CITY						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Croaker	3½ mi. E.	W. H. Davis	Coleman Whitaker	O	1897	0	200	3½	200	185	200
Diascond	2 mi. S.	—Brick Co.	H. E. Shimp	M	1908	250?					
Lee Hall	4 mi. S. W.	Duke & Smith	H. E. Shimp	O	1903	23	429	2			
Lee Hall	4 mi. S. W.	Duke & Smith	H. E. Shimp & S. H. Fetterhoff	O	1906	18	395	2	375	330	375
Lee Hall	near	H. M. Clement	S. H. Fetterhoff	D	1906	40				300	
Lee Hall	2 mi. W.	Charles Bailey	H. E. Shimp	M	1908	10	200	2	200		
Jamestown	at	Asso. Preservation of Va. Antiquities	Sydnor Pump & Well Co.	O	1905	12	270	6	270		270
Jamestown	1½ mi. NE.	C. F. Ayers	Frank Carman	O	1906	15	300	3	295	171-271	298
										15	
										45	
										190	
										260	
Jamestown	1½ mi. N.	Chas. Babcock	Frank Carman	D	1906	12	320	3	310	280	298
Jamestown	½ mi. E.	Miss L. J. Barney		O	1894	10	290	3			
Jamestown	1 mi. N.	G. L. Burleson	Frank Carman	O	1906	15	310	3	309		309
Jamestown	1½ mi. NE.	E. Gilley	Frank Carman	O	1905	18	298	3	298		
Jamestown	2 mi. E.	Miss Rose D. Johnson			1901	6	250?	7			
Jamestown		Southern Land Co.	—McCormick	O	1906	20	270	1½			
Lightfoot	1 mi. S. W.	Powhatan Hunting Club	S. H. Fetterhoff	D	1903	8	140	2			
Williamsburg	¼ mi. N. W.	Eastern State Hospital	G. Valden	M	1888	80	876	3-1			
Williamsburg	¼ mi. N. W.	Eastern State Hospital	Frank Gould	M	1902	84	280	8			
Williamsburg	¼ mi. N. W.	Marshall Estate	Frank Gould	M	1890	84	285	6			
Williamsburg	¼ mi. E.	Mrs. Israel Smith	G. Valden	M		88	299(?)	6			
Williamsburg	¼ mi. N. W.	William and Mary College	Frank Gould	M	1898	84	290	6	290	severl	280
Williamsburg	¼ mi. N. E.	G. Valden	Frank Gould	O	1888	70(?)	276	6			
Williamsburg	¼ mi. W.	Williamsburg Knitting Mill	Frank Gould	M	1889	75	286	6	286		286
Norge	near	Chesapeake & Ohio Ry.	Sydnor Pump & Well Co.	O	1909	110	419	8			415
KING AND QUEEN											
Gressith	2 mi. W.	W. F. Anderson	W. Johnston	O	1885	11	206	2	206	150	180
King and Queen	near	County	Frank E. Pearce	M	1889	20	216	2	216		216
King and Queen	2 mi. S. W.	S. Bird	Frank E. Pearce	M		18	200(?)				
Little Plymouth	2 mi. S. W.	R. H. Spencer		O	1886	20	168	1½			
Mantapike	½ mi. S.	Mantapike Canning Co.	Jos. Ryland	D	1903	6	150	2	150		36
Plainview	5 mi. N.	Garrett Post	Wm. Johnson	O	1888		210	2	210	215	
Shackelford	¾ mi. SW	W. H. Bland	J. V. Bray	O	1890		175	2	175	160	175
Shackelford	¾ mi. SW	R. M. Hart	Frank Pearce	O	1895	8	172	1½	172	160	172
Truhart	1½ mi. SE.	Miss E. B. Savage	J. V. Bray	D			175	2	175		
Walkerton		Dr. B. B. Bagby	W. H. Walker	O	1889	25	275				
Walkerton		Ivan Clark	H. E. Shimp	O	1906	21	240	1½	225		225
Walkerton		P. P. Dillard	Frank Eaton	O	1889	32	265	1½			20
Walkerton		H. B. Gray	Joseph Ryland	O	1889	35	250?				
Walkerton	2 mi. N.	A. B. Gwathmey	H. E. Shimp	O	1906	8	190	1½			7

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
Gravel.....	Calvert.....	Ft. +20	Gal. 20	Gal.	°F. 60(?)	Alkaline	Domestic and medic- inal
.....	Pamunkey	+30	10	.....	63½	.....	Drinking
.....	Pamunkey	+30	2	.....	65	.....	Domestic and stock
.....	.....	+25	.....	.....	.....	Soft	Boiler
.....	Calvert (?).....	+41	40-29	.....	65	.....	Drinking, domestic and stock
Gravel.....	Calvert (?).....	+30	78	.....	64	Fine	Household and stock
.....							
Gravel.....	Calvert (?).....	+40	¼	.....	63(?)	.....	Household and stock
.....	Calvert (?).....	+20?	2½	.....	63	.....	Household and stock
.....	Calvert (?).....	+41	70	.....	64	.....	Household and stock
.....	Calvert (?).....	+40?	6	.....	.....	.....	Household and stock
.....	Calvert (?).....	.....	5	.....	.....	.....	Household and stock
.....	Calvert (?).....	.....	¼	.....	60	.....	Stock
.....	Calvert (?).....	.....	2	.....	.....	.....	Drinking
White quicksand	.....	+38	.....	.....	.....	.....	No flow, abandoned
Sand	Calvert.....	+40	.....	50	62(?)	Soft	Hospital purposes
.....	Calvert.....	.....	.....	100	62(?)	.....	Hospital purposes
.....	Calvert.....	.....	.....	.....	.....	Hard, irony	Domestic
.....	Calvert.....	+34	.....	60	.....	.....	Drinking, etc.
.....	Calvert.....	+27	.....	150	.....	.....	Ice manufacturing
.....	Calvert.....	+38	.....	1,000(?)	.....	.....	Boiler and washing
Coarse green- sand.....	Pamunkey (?)...	+40	.....	200+	.....	Soft, alkaline	For locomotives, not used
Rock	Calvert.....	+28	8	.....	.....	Alkaline	Domestic and stock
Black sand.....	Pamunkey	+18	1	15	60¾	Soft, slightly sulphur	Public, no longer flows
.....	Pamunkey	+16	.....	10	61	.....	No longer flows
Shells.....	Calvert.....	.....	.....	3	.....	Good	Domestic and stock
.....	Calvert (?).....	+20	7½	.....	62	Soft	Canning factory
Under rock.....	Calvert (?).....	+6	15	.....	.....	Soft, sulphur	Domestic
Shell rock	Calvert.....	+20	5	.....	62½	Soft	Domestic and stock
.....	Calvert.....	+20	12	.....	62	Soft	Domestic
.....	Calvert.....	.....	.....	.....	.....	.....	.....
Sand under rock	Pamunkey	+30	1½	.....	58	Soft, sulphur	Domestic
Rock at 180.....	Pamunkey	+35	1¾	.....	62	.....	Household and stock
Sand	Pamunkey .....	.....	½	.....	63	.....	Household
.....	Potomac.....	.....	.....	2	60	.....	Drinking and stock
Greensand with shells	Pamunkey	+35	20	.....	63	.....	Household

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
KING AND QUEEN—Cont.											
Walkerton	near	W. T. Haynes.....	Frank Eaton.....	O	1889	Ft.	Ft. 260	In. 1½	Ft.	Ft.	Ft. 260
Walkerton	near	Hefron & Haynes Steamboat Co.	Frank Eaton.....	M	1888	5	185	1½	.....	.....	18
Walkerton	near	Mattaponi Piehle Co....	J. V. Bray	O	1904	8	330	1½	.....	.....	330
Walkerton	near	Mattaponi Piehle Co....	J. V. Bray	O	1902	6	260	1½	.....	.....	.....
Walkerton	near	John A. Mitchell.....	John A. Mitchell....	O	1891	32	372	1½	250	.....	.....
Walkerton	near	Mrs. C. T. Roberts.....	Joseph Ryland.....	M	1895	32	250	1½	.....	.....	.....
Walkerton	1 mi. E.	John N. Ryland.....	Joseph Ryland.....	O	1906	50	275	1½	275	.....	45
Walkerton	near	Miss Lucy Stacy.....	Joseph Ryland.....	M	1896	33	260?	1½	.....	.....	16
Walkerton	near	R. M. Trice	Frank Eaton.....	M	1889	.....	260?	1½	.....	.....	.....
Walkerton	near	Mrs. Mary Turner.....	Frank Eaton.....	M	1880	32	260	1½	.....	.....	.....
Walkerton	near	H. H. Walker.....	H. E. Shimp.....	O	1905	37	240	1½	.....	.....	20
Walkerton	near	Mrs. Melville Walker ..	.....	M	1889	35	270?	1½	.....	.....	45
Walkerton	near	Walkerton Pickle Co....	W. H. Walker.....	M	1904	.....	350	1½	.....	.....	.....
KING GEORGE											
Dido	at	C. E. Davis, 2 wells....	Chas. Pfeil.....	O	1898	8	175	1½	.....	150 90 15	.....
Dogue	2 mi. E.	J. S. Dickinson.....	L. Rude	O	1897	40	260	2	.....	.....	.....
Mathias Point..	.....	W. Mayo	L. Rude	D	1907	12	175	2	.....	.....	.....
Mathias Point..	at	P. H. Pemberton.....	C. W. Walcott.....	O	1902	8	236	1½	236	none	16 236
Pluck	near N.	Lyttleton Johnson....	Chas. H. Jones....	M	1895	6	190	2	190	none	.....
Pluck	near	Johnson Bros. ....	.....	M	.....	8	300	2½	.....	.....	.....
Pluck	¾ mi. N.	H. N. Stuart .....	.....	.....	1893	8	50	1½	42	.....	.....
Port Conway ...	2 mi. N.E.	J. H. Law .....	.....	M	1905	28	305	1½	.....	.....	.....
Port Conway ...	1 mi. E.	R. V. Turner	Hammell & Hale....	O	1905	20	250	1½	.....	.....	.....
Port Conway ...	near	R. V. Turner	Hammell & Hale....	O	1903	3	232	1½	224	15	219
Rollins Fork ...	2 mi. S.	Vulcan Fire Brick Co., (2 wells) .....	.....	M	1900	11	275?	1½	.....	.....	.....
Sealston	2 mi. E.	John Curtis	Geo. Heflin.....	D	1904	30	250	2	.....	.....	.....
KING WILLIAM											
Aylett	near	J. C. Fox	Jos. Ryland	D	1905	25	189	2	.....	none	20 30
Aylett	near	J. B. Moore.....	H. E. Shimp	O	1906	25	190	1½	180	.....	190
Cohoke	near N.	Cohoke Club	J. A. Smith.....	.....	1886	18	215	2	215	.....	.....
Cohoke .....	.....	Dr. Edwards	H. E. Shimp	D	1906	35	222	2-1	230	.....	230
Cohoke	1 mi. S.E.	J. W. Johnson.....	H. E. Shimp	D	1906	20	250	.....	240	.....	240
Elsing Green....	near W.	Roger Gregory	H. E. Shimp	D	1906	20	205	2	200	.....	190
Elsing Green....	.....	Roger Gregory	H. E. Shimp	D	1906	20	300	2	.....	.....	220
King William...	near	King William County...	F. E. Pearce.....	.....	1898	.....	350	.....	.....	.....	.....
King William...	1½ mi. N.	John Cook .....	.....	M	1889	4	260	1½	.....	.....	.....
Lester Manor....	3 mi. W.	J. T. Dantey.....	H. E. Shimp	D	1906	20	245	3-2	240	.....	240
Lester Manor....	3 mi. W.	Frank Robbins	H. E. Shimp	D	1906	40	400(?)	3-1	275	.....	70

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
	Pamunkey						Household
	Pamunkey		1½		61		Drinking
Gray sand	Potomac	+30?	5		63½	Soft, alkaline, sulphur	Salting pickles
	Pamunkey	+15	4		63		Salting pickles
Sand	Potomac	+30?			64		Household
	Pamunkey	+43?					
	Pamunkey	+25					
	Pamunkey	+33					
	Pamunkey	+33					Household
	Pamunkey		¼				Household
	Pamunkey	+32	⅓		60		Household
	Pamunkey	+35	⅓		60		Hotel
	Pamunkey	+35?					
	Potomac	+15				Soft, sulphur, alkaline	Pickle factory
	Pamunkey	+18	2½	6		Soft	Domestic, packing fish
	Potomac	+36				Hard	Domestic, stock
	Pamunkey						
Sand	Potomac	+10	2				Stock, domestic and irrigation
	Pamunkey	+8					Domestic, stock and oystermen
	Pamunkey	flows	several			Soft	Domestic, stock, too irony
Sand	Potomac	+3				Sulphur	Domestic, stock, too irony
	Pamunkey	+2		3		Very irony	Stock
	Pamunkey (?)	+29	2	3½	60		Household
	Pamunkey				61		House and stock
	Pamunkey	+23	13.5		61	Soft, slightly sulphur	Canning factory, domestic and stock
	Pamunkey		2		63		Drinking, boiler
"Quicksand"	Potomac	+31	1½			Soft, sulphur	Domestic
Gray sand	Pamunkey	+28	½		60½		Household and stock
Dark green sand	Pamunkey		1¾		60½		Household and stock
Dark sand	Pamunkey	+31				Soft, iron	Domestic, stock
"Soft rock"	Pamunkey	+35?	⅓	1		Soft	Household and stock
greensand	Pamunkey						
Greensand	Pamunkey	+32				Soft	
Greensand	Pamunkey	+30	5			Soft	Drinking and stock
	Pamunkey	+30	7		62		Drinking and stock
	Pamunkey						No flow, not used
	Pamunkey		3⅞		61		Household and stock, formerly boiler
"Shelly rock"	Pamunkey	+31	4		60?	Soft	Domestic and stock
Greensand	Pamunkey	+36	5		60?		Household and stock

TABLE 5 (Continued).—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
KING WILLIAM —Cont.											
Lester Manor....	3 mi. W.	J. A. Robins.....	H. E. Shimp.....	D	1907	Ft. 20	Ft. 200	In. 3	Ft. 200	.....	Ft. 190
Lester Manor....		T. L. Robins.....				36	260	3-2	250	19	240
Manquin	2 mi. S. W.	Miss Cora Skidmore...	Frank E. Pearce....	M	1888	32	270	2½	270	none	270
Manquin	1 mi. S.	C. B. Chapman.....	Sydnor Pump & Well Co.	M	1896	30	237	6	.....	.....	237
Palls	1½ mi. SW	J. H. Montague.....			1888	32	390	1½	398	.....	.....
West Point.....		City	Frank E. Pearce....	M	.....	8-15	165	1½	165	120	.....
West Point.....		City	Challenge Wind Mill & Feed Co. (2 wells)..	M	1904	10	335	3	337	165	.....
West Point.....	½ mi. N.	Mrs. S. E. Carr.....		M	1886	8	165	1½	.....	.....	.....
West Point.....	1 mi. N.	Denmead Bros.	J. V. Bray.....	O	1892	5	105	1½	105	.....	105
West Point.....	1 mi. N.	Denmead Bros.	Frank E. Pearce....	O	1895	2	158	1½	158	105	158
West Point.....	¼ mi. E.	B. W. Edwards.....	Frank E. Pearce....	M	1888	2	158	1½	.....	.....	.....
West Point.....	¼ mi. N.E.	Dr. W. T. Gatewood...	J. Frank Smith.....	O	1886	14	180	2	.....	.....	.....
West Point.....	1 mi. N.E.	Dr. W. T. Gatewood...	J. Frank Smith.....	O	1902	14	315	1½	.....	.....	.....
West Point.....	1 mi. N.W.	Guthrie & Kidd.....	J. V. Bray.....	M	1906	1-3	169	1½	169	.....	.....
West Point.....		B. W. Hefron.....		O	.....	7	165	.....	.....	.....	.....
West Point.....		B. W. Hefron.....		O	1903	7	325	.....	.....	.....	.....
West Point.....		B. W. Hefron.....		O	.....	7	120	1½	.....	.....	.....
West Point.....	1 mi. S.E.	J. W. Marshall.....	J. Frank Smith.....	M	1904	5	165	1½	.....	.....	.....
West Point.....	¼ mi. E.	J. W. Marshall.....	J. Frank Smith.....	O	1902	14	332	2	.....	.....	.....
West Point.....	¼ mi. S.	T. O'Conner .....			.....	8	165	1½	.....	.....	160
West Point.....	near S.	J. W. Owens.....	J. V. Bray.....	O	1899	20	165	1½	160	15	165
West Point.....	¾ mi. S.E.	M. M. Puller.....	J. Frank Smith.....	O	1902	8	325	.....	.....	.....	.....
West Point.....	1 mi. S.	Geo. W. Richardson...		O	.....	6	160	1½	160	120	.....
West Point.....	1 mi. S.	Geo. W. Richardson...	H. E. Shimp.....	O	1905	6	366?	4- 14	366?	120	300?
West Point.....	¾ mi. S.E.	Geo. W. Richardson...	Sydnor Pump & Well Co.	O	1904	10	325	1½	.....	.....	.....
West Point.....	½ mi. N.	J. W. Sheldon.....	J. V. Bray.....	O	1901	15	175	1½	.....	.....	.....
West Point.....	¾ mi. S.	^a Southern R. R. Co. (big well)		M	1881	5	120?	6	120	.....	.....
West Point.....	¾ mi. S.	Southern R. R. Co.... (6 wells)	Frank E. Pearce....	M	1888	5	160	2	160	.....	20 160
West Point.....	1 mi. S.E.	Southern R. R. Co....	E. Wilkinson	D	1900	5	165	1½	165	120	.....
West Point.....	1 mi. S.E.	Southern R. R. Co....	E. Wilkinson	D	1899	5	165	1½	165	120	.....
West Point.....	2 mi. S.E.	United States	E. Wilkinson	D	1893	.....	165	2	.....	.....	160
West Point.....	½ mi. S.W	West Point Ice Co. (2 wells)	Frank E. Pearce....	M	1888	6	185	2	185?	.....	185?
West Point.....	¼ mi. S.	Wm. Wheeler	J. Frank Smith.....	D	1902	8	326	1½	315	150	306
West Point.....	¼ mi. S.E.	E. Wilkinson	J. V. Bray.....	O	1887	10	165	1½	120	.....	.....

^aSouthern R. R. had about 15 wells.^bInitial head 29 feet.^cFlow at first 20 gallons per minute.^dCombined yield of wells.

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Greensand.....	Pamunkey	51½				Soft	
Sand	Pamunkey	1½				Soft	
	Potomac (?)	+39	2		61		Household and stock
Gray micaceous sand.....	Potomac (?)	+39	6½				Household, boiler supply, stock
	Potomac (?)	33	¾		61		Household and stock
	Calvert.....	+8		2-6		Soft	Public
Sand	Pamunkey	+20	37		66	Soft	City water works
	Calvert.....		2				Domestic
	Calvert.....	+9?	1½		62	Soft sulphur	Boiler
	Calvert.....	+10	20?		63	Soft	Drinking
	Calvert.....			12	62		Boiler
	Calvert.....	+11			67½		Household
	Pamunkey						Household
	Calvert.....	+13					Boiler at brick yard
	Calvert.....					Soft	Household
	Pamunkey					Soft	Household
	Calvert.....				65	Soft sulphur	Drinking
	Calvert.....	+14	10?		63		Washing oysters
	Pamunkey	+20			64½		Household
	Calvert.....		¾-				
Sand	Calvert.....	+18	2½		62		Stable
	Calvert.....		9½		61¾		Drinking
	Pamunkey		7½		67		Household
	Calvert.....		7		63	Soft	Washing oysters
Black sand.....	Pamunkey	+30?	70(?)		66	Soft	Washing oysters
	Pamunkey				65		Household
	Calvert.....		5		61¾		Household
	Calvert.....					Soft, sulphur	Drilled for locomotive, little used
	Calvert.....		4½			Soft	Drinking or steam-boats and wharf
Gravel.....	Calvert.....				63½	Soft	Drinking at Beach Park
	Calvert.....		7½		65?	Soft	Park at Terminal Hotel, drinking, etc.
	Calvert.....	+20	50?			Soft	Drilled for dredge, used now occasionally by boats
	Calvert.....		21	42	61¼	Soft	Ice mfg., drinking
Sand and gravel	Pamunkey	+18	20			Soft	
Sand	Calvert.....	+7		8	62		Domestic and stock

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
LANCASTER						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Bertrand	near S.	T. J. Ratcliffe & Co....	T. J. Ratcliffe.....	O	1889	9	272	1¼	268	220	90
Bertrand		J. C. Ewell (2 wells)....	L. T. Custer.....	O	1902	12	275	2		550	80
Irvington	1 mi. N.W.	Carter Creek Fish Guano Co.	R. H. Milligan.....	O	1899	6	580	3-2	580	450	580
Irvington	1 mi. N.W.	Carter Creek Fish Guano Co.					330	1½	330		
Irvington	¾ mi. SW	Est. of I. H. Francis....	R. H. Milligan	D	1905	5	537	3			
Irvington	¾ mi. SW	Est. of I. H. Francis....				6	330?	1½			
Irvington	near	W. A. Dameron & Bros.	L. Rude	O	1891	3½	330	1½	330		
Irvington	near	Messick & Gunby.....	H. A. Crittenden....	O	1903	4½	450?	1½			
Kilmarnock	near		R. H. Milligan.....	D	1903		637	2			
Lancaster		Wm. Chilton					250	1½			100
Lancaster	near	County	L. Rude	M		77	450				
Merry Point	near	Crallé, Jones & Co.....	J. C. Ewell.....	M	1902		325	2½	325		100
Millenbeck	near S. E.	Millenbeck Oyster Co....	L. F. Carter.....	M	1892	10	315	1½		none	one
Monaskon		W. Warren	H. E. Shimp.....	D	1904		325	1			
Monaskon		B. L. Farinholt.....		O	1889	6	300	1½			
Monaskon		B. L. Farinholt.....				6	255				
Ocran		J. F. Bellows				6	507	3			
Ocran		Bellows & Squires.....	R. H. Milligan.....	O	1907	10	660	3	660		660
Weems		B. G. Doggett and Chas. Chance	L. Rude	M	1896	3½	330	1½	330		
Weems		B. G. Doggett and Chas. Chance	L. Rude		1894		260	1½			
Weems		W. Messick	H. E. Shimp.....	D	1904		485	2-1			
Westland		B. L. Farinholt.....		M	1896		443				
Wheaton	1½ mi. W.	O. D. Hale.....	Hammell & Hale.....		1904	10	244	1½	233		
Wheaton	near	Lewis, Lankford-Tull Co.	Hammell & Hale.....	D	1902	8	256	1½	251	none	214
Wheaton	near	J. W. Wheaton			1894	6	262	1½			
Wheaton		Wheaton Packing Co.			1894						
Wheaton		(3 wells)	Hammell & Hale.....		1903	4	265	1½		70	
Whitestone	near				1890		300+				
MATHEWS											
Fitchetts		Fitchetts	J. W. T. Robertson ..		1904		100±	2			
Mathews	near	County	H. E. Shimp.....	M	1905	2	817	2-1		125	
Mathews	near		Hammell & Hale.....	M		8	390				
Mathews	3 mi. S.	R. T. Sears	Wm. S. Johnson.....	M	1891	8	300±				
Mathews	near		G. E. Steer.....	M	1891	8	360±				
Port Haywood	1½ mi. E.	Sterling Diggs	H. E. Shimp.....	O	1904	10	112±	3-2			
Port Haywood	1½ mi. N.	Perry Lumber Co.....	H. E. Shimp.....	D	1907	10	107	3-2	100		100
Traders	1 mi. N.	John M. Campbell.....		D	1907	15	110	3-2	100		

^aFlow at first 45 gallons per minute.

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
Sand	Calvert.....	Ft. +18	Gal. 1½	Gal.	°F.	Sulphur	Domestic, stock, washing oysters
Clay.....	Calvert.....	+18	2	.....	.....	Soft	Domestic, stock, washing oysters
Sand	Pamunkey (?)...	+35	30	.....	69	Soft	Boiler, domestic and stock
.....	Calvert.....	.....	.....	.....	.....	Soft sulphur	Not used
.....	Pamunkey (?)...	.....	83½	.....	69	.....	Drilled for hotel supply, household
.....	Calvert.....	.....	1¼	.....	65	Soft, sulphur	Household
.....	Calvert.....	+4	½	.....	64	Soft, sulphur	Drinking
.....	.....	+6?	2	.....	64	Soft	Drinking, washing oysters, canning
.....	UpperCretaceous	.....	140	.....	.....	.....	.....
.....	Calvert.....	.....	.....	.....	.....	.....	.....
.....	Calvert.....	+15	.....	.....	.....	.....	.....
.....	Calvert.....	+32	.....	.....	.....	.....	No flow, abandoned
.....	Calvert.....	+4?	½	.....	.....	Sulphur	Domestic, stock, boiler
.....	Calvert.....	+0	.....	.....	.....	Sulphur	Drinking, cooking
.....	Calvert.....	+12	50-12	.....	.....	Soft, sulphur	Domestic and boats
.....	Calvert.....	.....	7	.....	.....	.....	.....
.....	Pamunkey (?)...	.....	.....	.....	.....	.....	.....
Sand	UpperCretaceous	.....	.....	.....	.....	.....	Fish factory
.....	Calvert.....	+6	2½	.....	64	Soft, sulphur	Drinking
.....	Calvert.....	.....	.....	.....	.....	.....	.....
.....	Calvert.....	.....	.....	.....	.....	.....	.....
Porous sand rock	Calvert.....	+18	15	.....	.....	Soft	No flow, abandoned
.....	.....	.....	.....	.....	.....	.....	Domestic and stock
Shell rock	Calvert.....	.....	16	.....	61(?)	Soft	Canning factory, domestic and stock
.....	Calvert.....	.....	.....	.....	.....	.....	Domestic and stock
.....	Calvert.....	+15	20	.....	.....	Soft, sulphur	Canning factory, domestic and stock
.....	.....	.....	.....	.....	.....	.....	No flow, abandoned
.....	St. Marys (?)...	.....	.....	.....	.....	.....	Canning factory
.....	.....	+6½	1	.....	59	Soft, sulphur	Drinking
.....	.....	.....	.....	.....	.....	.....	Never used, no flow
.....	.....	.....	.....	.....	.....	.....	Never used, no flow
.....	.....	.....	.....	.....	.....	.....	Never used, no flow
Fine sand	St. Marys (?)...	+5	.....	very small	.....	Sulphur	Abandoned
.....	St. Marys.....	+7	.....	30	58	Soft	Boiler, drinking and stock
.....	St. Marys.....	.....	.....	.....	57½	.....	Domestic and stock

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
						Ft.	Ft.	In.	Ft.	Ft.	Ft.
MIDDLESEX											
Bushy						300+					
Butylo	1½ mi. S.E.	B. L. Farinholt.		M	1895	0	280	1½			
Bayport	¼ mi. S.E.	Bland Bros.	Hammell & Hale.	D	1902	7	248	1½	242	none	218
Bayport	near	R. H. Bland & Co., 3 wells	Hammell & Hale.	O	1894-1906	6	260-300	1½			
Bayport	near	B. L. Farinholt.	L. Rude	M	1891	6	300	1½			
Dew	near	L. Nelson	L. Rude	O	1894	4	297	1½			50
Sandy Bottom.	1 mi. E.	D. A. Taylor.	J. W. T. Robertson	O	1901	7	78	2	75	35	74
Urbanna		G. S. Chowning.	H. E. Shimp.	O	1900	5	250	1½			
Urbanna		G. W. Hurley.	R. H. Milligan.	D	1904		478	3			300
Urbanna		G. W. Harley, (2 wells).	H. E. Shimp.	D	1901	4	290	1½			
Urbanna		G. W. Harley, (2 wells).	L. Rude			2	227	1	227		70
Urbanna	¼ mi. E.	Hoskiss & Donaldson.	G. P. Beazeley.	O	1896	6	272	2	272		
Urbanna		Urbanna Mfg. Co.		M	1902	2	275?	1½			
Urbanna		G. V. Wagemen.	G. V. Wagemen.		1905	6	232	1½			
NANSEMOND											
Chuckatuck	1 mi. E.	Dr. Livins Langford.	Tom Johnson.	O	1906		188	2			
Chuckatuck				M	1908	25	300		300		
Everets	1½ mi. E.	Josiah Gray	E. E. Wagner	D	1904	36	100	1¼	50		
Everets		G. A. Greene.	E. E. Wagner	D	1904		90	1¼			
Everets		H. Saunders.	E. E. Wagner	D	1904	5	50	1¼			
Everets		T. J. Saunders.	C. M. Johnson.	O	1896	5	54	1¼	50		
Everets		E. E. Wagner	E. E. Wagner.	D	1900	8	100	1¼	100	50, 80	80
Reids Ferry		Nansemond River Brick & Tile Co.		O	1902	15	150	2			
Suffolk	1 mi. E.	A. B. Cramer.	A. B. Cramer.		1905	55	253				
Suffolk	½ mi. N.E.	Gay M'fg Co.	Sydnor Pump & Well Co.		1896	55	300				
Suffolk			Leach		1885		250				
Suffolk		Norfolk & Portsmouth Traction Co.	Sydnor Pump & Well Co.		1901	58	803?	6	650?		
Urbanna		L. B. Wageman.		M		5	250	1½			
Urbanna	near		R. H. Milligan.	D	1906	10	590	3		300	300
Waterview		Powell & Son.	Geo. Hefflin.		1906		350	2			
NEW KENT											
Boulevard		Wm. Weber	Sydnor Pump & Well Co.	O	1902	22	260	4½	265	224	52
Lanexa		Robert Turner	H. E. Shimp.	M	1908	28(?)	110	2	110		
Lily Point		Richmond Shooting and Hunting Club	H. E. Shimp.	D			225	1½			220
Plum Point	near	Frederick Knoll	J. V. Bray.	O	1897	9	150	1½	150		35
Plum Point	½ mi. S.E.	J. L. Richardson.	Frank E. Pearce.	O	1891	12	168	1½	168	120	165
Providence Forge	½ mi. E.	R. E. Richardson	P. H. Sweet.	M	1896	25(?)	215	1			100?

*Initial flow 25 gallons per minute.

*Flowed at first.

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
.....	Chesapeake					Soft	Not used
.....	Calvert	+16	20			Sulphur	General
Shell rock	Calvert		16			Soft	Domestic, stock, canning factory, packing
.....	Calvert	+20				Hard (?)	Drinking and cooking
.....	Calvert	+18	20		64		Washing oysters, drinking
Rock	Calvert		½			Soft, alkaline	Drinking
Gravel	Columbia(?)	+2				Hard, irony	Domestic except laundry
.....	Calvert		3				Drinking, etc., at boat yard
.....	Pamunkey	+25?	75		68		Making ice
.....	Calvert				66½		Making ice
.....	Calvert	+15	3	105			Making ice
Under rock	Calvert	+12	3			Soft, sulphur	Boiler, pickling cucumbers
.....	Calvert					Soft, sulphur	Household
.....	Calvert	+10	5		65½		
.....	St. Marys						No flow, abandoned
.....	St. Marys	+30				Soft	
.....	St. Marys	+17					Household
.....	St. Marys						Household
.....	St. Marys						Household
Sand	St. Marys	+9	⅓		58		Household and stock
White sand	St. Marys	+15	2½			Soft	Household
.....							No flow, abandoned
.....							No flow, abandoned
.....							No flow, abandoned
.....							No flow, abandoned
Sand	UpperCretaceous	+32		11			Ice making
.....	Calvert				63		Canning factory
.....	UpperCretaceous	+34		105	67		Not completed
.....	Calvert						
Soft	Pamunkey	+32					
Sand	Pamunkey						
White sand with black	Pamunkey	+40?	3				
Shell rock	Chesapeake				58?	Lime?	Domestic and stock
Sand	Chesapeake	+12				Soft	Domestic and stock
.....	Pamunkey	+15 ^b			60½		Store, household

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
						Ft.	Ft.	In.	Ft.	Ft.	Ft.
NEW KENT—Cont.											
Providence Forge	1/2 mi. NW	E. B. Townsend	Sydnor Pump & Well Co.	M	1902	20	216	4 1/2	216		215
Providence Forge		James Christian	H. E. Shimp	M	1908	25(?)	215	2	215		
Providence Forge		Southern Pine Lumber Co.		M	1907	25	220	2			
Whitehouse	near S. E.	Southern Railway	P. H. Sweet	D	1893	5(?)	200	1 1/2	200		
Walkers	near	—McCann	H. E. Shimp	M	1909	25	200	2	200		
NORFOLK											
Buell		E. H. Barney Co.									
Buell	1 1/2 mi. N.	Pocomoke Guano Co.	Walter Goodman	O	1906	6	86	2 1/2	86	12	82
Buell	N.	Roanoke R. R. & Lumber Co.					53	1 1/2	53		
Buell							562	5			
Buell		Norfolk Crosoline Co.					50-75	2	60		
Greatbridge	1/2 mi. N.	J. E. Hall	J. E. Hall	O	1902	5	75	3	70		
Buell							562				
Lambert Point		Norfolk & Western R. R.	A. L. Miller	O		13	616	12-3	6	110	603
Pimmers Point		Va.-Carolina Chem. Co.	J. H. K. Shannahan		1903		40	4	40		
Piney Beach	3/4 mi. N.E.	Jamestown Exposition Co.	Norfolk Mfg. & Supply Co.	O	1906	10	50	2 1/2	10	none	
Norfolk		City		M		10	140	6			
Portsmouth		Portsmouth Retail Lumber Corporation			1907	13	48	1 1/2			
Rixton		Geo. S. Bunting	Geo. S. Bunting	O	1890	10	575	2-1			260
											10,
											20,
											30,
											40,
											90
NORTHAMPTON											
Cape Charles	1 1/4 mi. SE	New York, Phila. & Norfolk R. R. (24 wells)	T. M. Ward	O	1900	8	40, 90	3		8	
Cape Charles		Wharton Fisheries Co.	R. H. Milligan	D	1899	3	249	3			
Cape Charles		Scott Estate									
Cape Charles		Town and 17 wells	Eclipse Windmill Co.	M	1886	12	400				
Cape Charles		Heckle & Kellogg		M		10	16-40				
Capeville	3 mi. E.	J. H. Roberts	J. W. T. Robertson	O	1902	1	189	1 1/2	125		
Cheriton		Huff Bros.	Huff Bros.	O			63	2	16		
Mockham Island			J. W. T. Robertson				189				
Nassawadox		W. A. Jones (2 wells)		O	1906	3	75	1 1/2			
Nassawadox	2 1/2 mi. NE	Thomas Upshur	W. M. E. Tilghman	D	1904	5	127	1 1/4			
Oyster	near	W. T. Travis	J. W. T. Robertson	D	1901	3	185	1 1/2	171		
Oyster		W. T. Travis	J. W. T. Robertson	D	1901	3	205	1 1/2	175		
Oyster							175-				
Oyster		W. T. Travis (3 wells)	J. W. T. Robertson	M	1901		200	1 1/2			
Bone Island	8 mi. E.	Ashton Starke		O	1906	6	169	1 1/2	169		
Willis Wharf		W. Ballard	J. T. Walkley	D	1905	15	98	1 1/2	98	46	
										18	

*Initial flow 65 gallons.

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Sand	Pamunkey	+27?			61		Domestic
Sand	Pamunkey	+20					Domestic
Sand	Pamunkey	+25					Drinking and boiler
Blue sand	Pamunkey	+13	1½			Soft	Domestic
Sand	Pamunkey	+15					Domestic
Gravel, sand and shell	Columbia	±0				Hard	Boiler and domestic
Sand	Columbia (?)	+10				Irony	Drinking
Gravel	Columbia (?)	+1½?			70		Not used
	Columbia (?)	+8				Hard	Domestic and stock
	Calvert (?)	+5				Alkaline, saline	Domestic, stock and boiler
Fine micaceous sand		+28	51		72	Saline	Drinking, washing
Gravel	Columbia		30			Salty	Domestic
Sand and gravel	Columbia	±0				Alkaline	Drinking, boiler
	Yorktown (?)	+4				Irony	Abandoned
Gravel	Columbia						No flow, abandoned
Sand	Columbia	+0		100			Locomotives, machine shops
Gravel and sand	St. Marys (?)	+1	10	80		Brackish	Boiler
							No flow, abandoned
Shells	Chesapeake (?)	-½				Good	Town supply, making ice
	Columbia						Domestic and stock
	Columbia	±0					Domestic
	Columbia	+4					Domestic and stock
	Columbia (?)	+6	1½				Domestic and stock
	Chesapeake		2			Soft, slightly sulphur-bearing	Domestic
	Chesapeake		2				Domestic
	Chesapeake						Boats, domestic and drinking
Sand	Chesapeake	-6	¾			Soft, slightly sulphuretted	Drinking, etc.
Shells	Columbia					Hard	Domestic

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
NORTHUMBER- LAND											
Bond Point.....	near	A. M. Byers.....	Chas. H. Jones.....	M	1903	5	200(?)	11½	265		
Bond Point.....			L. Rude.....	O	1888	53?	265	11½	265		
Coan.....	near	T. H. Fallin.....	L. Rude.....	O	1888	53?	265	11½	260		
Coan.....	near	T. H. Fallin (2 wells)....	Chas. H. Jones.....	O	1896	1½	270	1½	260	240	
Coan.....		T. H. Fallin.....	T. H. Fallin.....	O	1898	0	310	1½	300	240	90
Coan.....	3 mi. N.	T. H. Fallin.....		O		3	290				
Coan.....		T. H. Fallin.....		O		4	318				
Cowart.....	near S. E.	S. Cowart.....	Hammell & Hale....	O	1903	5	310	1½	310	280	150
Cowart.....		J. L. Dobyens.....		M			288	2			310
Cowart.....		L. Hedley.....									
Fairport.....	near S. E.	McGill & McNeal Co....	R. H. Milligan.....	O	1903	3	690	2	690		
Fairport.....			J. H. K. Shannahan	M	1898	6	662		650		
Fairport.....		Morris-Fisher Co.					393	1½			
										240	
										400	
										692	
										710	
										721	
Fleeton.....	½ mi. SW	Fleets Point Devel. Co...	R. H. Milligan.....	O	1904	8	746	2	746	721	
Fleeton.....		Fleets Point Devel. Co...	R. H. Milligan.....	D			690	2			
Heathsville.....	1 mi. N.	W. C. Snow.....	S. E. Booth.....	O	1896	5	265	2	265	none	
Hyacinth.....	2 mi. S.W.	Roland Park.....	Chas. H. Jones.....	O	1904	5	270(?)	1½			
Hopeside.....		S. A. Whittaker.....	S. A. Whittaker.....	O	1904	8	365	4	365		20
							325-				
Lewisetta.....		Gavner Bros.....		M			700				
Lewisetta.....		C. R. Lewis & Co.....	J. H. K. Shannahan	O	1894		317	5-2			
Lodge.....	½ mi. S.	Benj. Chambers (3 wells)	L. Rude.....				255	1½	240	none	100
Mila.....	near	Hinton-Toulson Oil & Guano Co.....	R. H. Milligan.....	O	1904	10	685	3	635	none	600
Mundy Point.....				M			270(?)	2			
Mundy Point..	near E.	W. J. Courtney.....	N. M. Shannahan...	O	1899	6	268	6			
Reedville.....	near S.W.	Edwards & Reed Co....	R. H. Milligan.....	O	1902	5	685	2	682	350	
Reedville.....		Haynie & Snow Co.....	R. H. Milligan.....	D			683	2			
Reedville.....		Jas. C. Fisher.....	R. H. Milligan.....	M	1904		698	2	698	400	
Reedville.....		McGill-McNeal Co.....	R. H. Milligan.....	D	1903	3	680	3	680		
Reedville.....	near	McNeal-Edwards Co....	R. H. Milligan.....	O	1902	5	682	2	682		
Reedville.....	near	Albert Morris.....	R. H. Milligan.....	D	1904	8	724	2	690	none	690
Reedville.....		Morris & Fisher Co....					405				
PRINCESS ANNE											
Virginia Beach..		Princess Anne Hotel....			1890	8	73	2			
Virginia Beach..		Princess Anne Hotel....			1889	8	600				
										783,	
Waterway.....		Norfolk City Water Wks.	C. L. Parker.....		1898	11	1,750	12-4½	1,480	1,750	

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
	Calvert.....	Ft.	Gal.	Gal.	°F.		
	Calvert.....	flows	1½				
	Calvert.....	+12	¾		63		Drinking
	Calvert.....	+10	1½				Canning factory and domestic
	Calvert.....		7½				Canning factory and domestic
	Calvert.....		1				Domestic
	Calvert.....		1				Domestic
Rock	Calvert.....	+8	3			Soft, slightly sulphur.....	Drinking
	Calvert.....	+6	2				Domestic
Sand	UpperCretaceous	+35	45			Soft	Boiler at fish factory
Sand	UpperCretaceous	+30	75				
	Calvert (?).....		2			Soft	
Sand	UpperCretaceous	+35	40			Soft, alkaline	Boats, domestic and stock
	UpperCretaceous		10			Soft, alkaline	Boats, domestic and stock
Sand	Calvert (?).....		3			Soft, sulphur	Drinking
Gravel and sand	Calvert.....		1¼		62½		Not used
Gravel.....			8-18				
Porous rock.....	Calvert.....		17				
	Calvert.....	+14			62	Slight sulphur	Boilers, domestic
Rock at 500							
Black sand.....	UpperCretaceous	+40	45			Soft, alkaline	Fish factory boiler
	Calvert.....		1, ¼			Soft	Household and stock
	Calvert.....	+12				Soft, alkaline	Washing oysters
Sand	UpperCretaceous		33	30		Soft	Fish factory, boiler and drinking
	UpperCretaceous		45				
	UpperCretaceous		18				
Sand	UpperCretaceous	+38	50			Soft	Fish factory boiler
Sand and gravel	UpperCretaceous	+25	35			Soft, alkaline	Fish factory boiler and drinking
Sand	UpperCretaceous	+38	40	200		Soft	Washing, drinking
	UpperCretaceous						
	Columbia					Irony	Washing, etc., no longer used
							No flow, abandoned
Sand	Upper Cret's (?)	+25?	75		76	Saline, sulphur	Part of public supply

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
PRINCESS ANNE —Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Waterway		City of Norfolk.....			1894	.....	730	6-8	730	12, 300	....
PRINCE GEORGE											
Blairs	2 mi. W.	David Dunlap	A. L. Davis.....	M	1903	65	307	4	.....	60	....
City Point.....	½mi. NW	Misses Epps	Sydnor Pump & Well Co.	O	1905	55	111	6	103	85	108
City Point.....	½mi. NW	Misses Epps		O		55	53	8	.....		....
PRINCE WILLIAM											
Agnewville	near E.	Rufus Davis	Henry Daniels.....				65	6	45	.....	....
Myron		Washington Fertilizer Co.	W. C. Miller	D	1901	.....	257	4	238	127	256
RICHMOND											
Downings		W. B. Hale	Hammell & Hale.....		1901	8	241	1½	232	.....	81
Iyondale	near E.	Mrs. J. H. Lemoine.....		O	1889	50	254	2½	.....	.....	....
Naylors		A. A. Taliaferro.....	H. E. Shimp.....	D	1904	.....	320	1	.....	.....	....
Naylors	near S.	Waddington & Holme...	L. Rude	O	1894	.....	320	1½	225	160	....
Naylors	near S.	Waddington & Holme...	L. Rude	O	1893	5	386	1½	386	250	386
Sharps	¾ mi. NW	P. Y. Barber	L. Rude	O	1899	15	240	1½	240	160	....
Sharps		A. J. Davis.....					325	.....	.....	200	....
Sharps		F. Downing					325	.....	.....	200	....
Sharps	1 mi. N.E.	J. M. McCarty.....	L. Rude	O	1894	10	240	2	240	.....	....
Sharps	¼ mi. NW	D. W. C. Sharp (2 wells)	L. Rude	O	1890	4	212	1½	212	90	....
Sharps	¼ mi. NW	E. Sharp	L. Rude	O		3	230	1½	.....	.....	188
Sharps	¼ mi. NW	G. L. Smith & Bro. (2 wells)	L. Rude	O	1903	+8	245	2	245	.....	....
Sharps	¼ mi. NW	J. B. Smith	L. Rude		1888	15	255	1½	250	.....	....
Sharps	¼ mi. NW		L. Rude	D	1907	4	440	1½	365	.....	....
Warsaw	3 mi. E.	E. W. Garland.....	L. Rude	O	1899	11½	188	2	187	65	185
Warsaw		E. W. Garland.....	E. W. Garland.....		1893	10	68	36	68	.....	....
Warsaw	3mi. S.	W. A. Jones (2 wells)...	W. S. Johnson.....	M	1890	22	200	1½	200	.....	....
Warsaw	3mi. S.	M. D. Kalbach	—Hale	O	1906	8	181	1½	177	.....	176
Warsaw	3mi. S.	G. M. Sydnor (2 wells)...	—Hale		1906	3	180	1½	177	.....	177
Warsaw	2 mi. E.	Totuskey Canning Co....	H. E. Shimp.....	M	1899	5	177	1½	.....	.....	50
Warsaw		Frank Garland	Hammell & Hale.....		1902	.....	165	.....	.....	.....	....
Wellfords	2 mi. S.E.	W. G. Brockenbrough...	L. Rude	O	1904	.....	366	¾	366	180	300
Wellfords		H. T. Douglas, Jr.....	Hammell & Hale....	O	1894	20	227	2	227	60, 190	....
Wellfords	near N.	Frank Garland	Hammell & Hale....	O	1902	4	161	1½	165	.....	114
SOUTHAMPTON											
Arringdale	near	Camp Manufacturing Co. (4 wells)	J. T. Moore and others	D	1891	30	75	1½	75	.....	30
Boykins		W. D. Barden		M			90	2	.....	.....	....

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal. 35	Gal.	°F.		Not used
		+30					No flow, not used
Sand	Patuxent.	+15		25			Household
	Pamunkey						Abandoned
Gravel						Hard	Domestic
Coarse sand and gravel	Patuxent	55		320		Soft	Boiler, domestic
Rock at 200							
gravel							
sand rock	Calvert	+18	18			Soft	Domestic
	Calvert	+6				Hard, iron and sulphur	Household
	Pamunkey						
Black sand	Pamunkey	+30	2				Domestic and canning factory
	Pamunkey	+25	3		63		Domestic and stock
Sand	Calvert	+12				Soft	Household and stock
	Pamunkey	+20					
	Pamunkey	+20					
Gravel	Calvert	+26	530		63	Soft	General
Sand	Calvert	+16				Soft	Washing oysters
Rock	Calvert	+9				Soft	Canning factory
Gravel	Calvert		4			Soft	Washing oysters, drinking
Gravel	Calvert	+14				Soft	Household
Fine gray sand	Pamunkey (?)					Soft	
Sand	Calvert	+36	16		62½	Soft, sulphur	Drinking
	Calvert	+30	16				
	Calvert		¾		60		Domestic
Sand	Calvert	+20	2		61		Boiler at saw mill
Black sand	Calvert	+20	12		62		Drinking and canning factory
	Calvert	+20	5		62		Canning factory
Rocky clay	Calvert						
Clay	Pamunkey	+20	5		62?	Soft, sulphur	Household and stock
Rock	Calvert	+40	3½			Sulphur, iron	Household
Shell rock	Calvert	+22	24			Soft	Tomato canning factory, drinking
	St. Marys	+40?	6			Hard	Domestic and stock
	St. Marys	+10				Slightly alkaline	

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
SOUTHAMPTON—Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Boykins		J. W. Drury		M		105	2	1 1/2			
Boykins		E. H. Grizzard		M		87	2				
Boykins		M. J. Knight		M		98	2				
Boykins		R. M. Knight		M		110	2				
Boykins		Henry de Laathe		M		90	2				
Boykins		F. M. Powell	P. P. Ellis	M		100	2				
Boykins	near	W. A. Powell	P. P. Ellis	O	1903	85	2		85	none	85
Boykins		Town of Boykins		M		85	2				
Boykins		W. W. White	J. T. Moore	M		130	2				
Branchville	near	P. G. Ellis	R. G. Ellis	O	1901	250	2	250	15		
Branchville	near	P. P. Ellis	P. P. Ellis	O				235	150		
Branchville	2 mi. S. E.	B. H. Beale	P. P. Ellis	D		15(?)	130	1			
Branchville	near	Grizzard Bros. & Co.	P. P. Ellis	M				150			
Branchville	near	T. J. Harrell	George Wilkins	M		35	207	2	90		
								140			
								160			
Branchville	near	T. E. Peat	P. P. Ellis	D		20	130	1 1/2	130		
Capron		Trent & Vinson		O		50(?)	400	2			
Capron		Trent & Vinson		O		50(?)	225	2			
Courtland		R. F. Whitfield	J. T. Moore	D	1910	28	165	2			
Courtland		Bain & Co.	J. T. Moore	M			140	2			
Courtland	near	Town	J. T. Moore	D			125	2	125		
Courtland		Williams & Ketcham	J. T. Moore	D			160	2			
Courtland		W. Shands		D			170	2			
Courtland	near	W. J. Sebrall		D			160	2			
Courtland	2 mi. S.	W. A. Howell	J. T. Moore	D	1909	15(?)	207	2			
Delaware	near	Seaboard Air Line	George Wilkins	M			175	2			
Franklin	1/2 mi. N.	Camp Manufacturing Co.									
		(17 wells)		M		10	130	1 1/2	130		
Franklin		J. L. Camp		O		70	190	2			
Franklin		E. H. B. Cobb									
Franklin		P. F. Darden					177	2			
Franklin		W. H. L. Goodman		O		22	154	2			
Franklin		Goodman & Barrett		O		22	142	2			
Franklin		O. W. Hayes		O		18	150	2			
Hugo	near	Farmers' Mfg. Co.	P. P. Ellis	D	1908		125	2	125	none	
Sands		T. H. Barrett	P. P. Ellis	D			222		222		
Sebrall	near	Tidewater Railway Co.	Sydnor Pump & Well Co.								
Storeys	near	J. T. Moore	J. T. Moore	O	1907	58	344	10			344
Sedley	near	Philip Rogers	J. T. Moore	O		55(?)					
				O		60	200	2 1/2			
SPOTTSYLVANIA											
Fredricksburg	1/2 mi. NW	E. D. Cole	Alexander	O	1902	50	152	2	150		150
SURRY											
Bacons Castle	near	W. A. Warren	A. L. Spandour		1896	84	460	4			80
Bacons Castle	4 mi. E.		A. L. Spandour		1894	22	400+	1 1/2			
Dendron		Surry Lumber Co.			1888	125	386	6			
							315				
Homewood	2 mi. S. E.	W. F. Gray	Whitmore	M	1889	5	219	1 1/2			
Homewood	1/2 mi. SW	W. F. Gray	Whitmore	M	1888	5	250	1 1/2			
Homewood	1 mi. NW	W. F. Gray	Whitmore	M	1888	5	240	1 1/2			

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
SURRY—Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Homewood	near	W. F. Gray.....	A. L. Spandour.....	M	1887	6	330(?)	1½	.....	.....	.....
Homewood	at	W. F. Gray.....	A. L. Spandour.....	M	1887	6	330(?)	1½	.....	.....	.....
WARWICK											
Leehall	near	J. Clements	S. H. Felterhoff.....	D	1906	43	460	2	.....	.....	.....
Menchville				M	.....	25	300	.....	.....	.....	.....
Mulberry Is.	S.	Phillip Lederhor	H. E. Shimp.....	O	1904	5	384	2-1	.....	.....	.....
Mulberry Is.	at	P. H. Wright.....	H. E. Shimp.....	O	1900	10	370	1	370	275	....
Newport News.....		Old Dominion Land Co.		O	.....	30	582	.....	.....	.....	.....
Newport News.....		Old Dom. Brewing Co..	H. E. Shimp.....	D	1907	.....	500	2	.....	.....	.....
Tidewells	near N.	C. E. Daiger	Chas. H. Jones.....	O	1896	8	225	2	.....	.....	180
				O	1898	.....	235-	.....	225-	.....	.....
Tuckerhill	3 mi. E.	J. R. Dor Passor.....	Chas. H. Jones.....	O	1906	5-15	250	1½	235	.....	40
		(15 wells)									
Tuckerhill	3 mi. S.E.	J. R. Dor Passor.....	Chas. H. Jones.....	O	1903	1	90	1½	70	.....	70
Tuckerhill	3 mi. S.E.	Chas. H. Jones.....	Chas. H. Jones.....	O	.....	.....	245	1½	.....	.....	120
Tuckerhill	3 mi. N.W.	Jas. S. Sydnor.....	Chas. H. Jones.....	O	1894	14	248	2	240	228	64
White Point.....	at	D. W. Allen.....	Jones & Allen.....	O	1896	.....	240	1½	240	.....	80
White Point.....	½ mi. S.	D. W. Allen.....	Chas. H. Jones.....	O	1898	.....	240	1½	240	.....	80
White Point.....	½ mi. N.E.	G. L. Wilson.....	Chas. H. Jones.....	O	1901	10	216	2	210	12, 20	28
Wilkerson	½ mi. N.	Gouldman Bros.		O	.....	.....	240	1½	.....	.....	.....
Wilkerson	1 mi. W.	L. C. Hardy.....	Chas. Pfeil	O	1904	20	248	1½	.....	.....	.....
Wilkerson	1 mi. W.	L. C. Hardy.....	E. Gouldman	O	.....	30	470	.....	.....	.....	.....
Wilkerson	near	W. S. Wilkerson.....	Chas. Pfeil	O	1903	4	235	1½	.....	.....	.....
Wilkerson	near	W. S. Wilkerson.....	Chas. Pfeil	O	1906	7	235	1½	.....	.....	.....
Zacata	3 mi. W.	W. E. Goodridge.....	Chas. H. Jones.....	O	1904	12½	160	1¼	158	.....	45
Zacata	3 ½ mi. E.	Westmoreland Oyster Packing Co.	Chas. H. Jones.....	O	1900	3½	158	2- 1¼	152	.....	40
WESTMORELAND											
Bealer	near	Beale & Biddle.....	Chas. Jones	O	1899	2	175	1½	172	.....	.....
Chiltons		Hardwick & Sanford...	Chas. Jones	O	1903	10	155	1½	155	.....	.....
Coles Point.....		E. C. Barnes.....			.....	.....	220	1½	.....	.....	.....
Coles Point.....	¼ mi. S.E.	John Bronson.....	Chas. Jones	O	1896	5	216	1½	205	.....	85
Coles Point.....		S. W. Godman.....			.....	.....	207	.....	.....	.....	.....
Coles Point.....	¼ mi. E.	Wm. Mayo.....	L. Rude	D	1907	15	360	1½	350	220	350
Colonial Beach..	near N.W.	Theodore Barnes.....		..	1902	10	240	1	240	.....	.....
Colonial Beach..	½ mi. S.W.	Mrs. Bell		O	1890	9	200	.....	.....	.....	.....
Colonial Beach..	½ mi. N.E.	M. A. & E. S. Bentley.		O	1894	10	200	1¼	200	.....	.....
Colonial Beach..	½ mi. S.W.	D. C. & L. J. Connelly	Chas. Pfeil	..	1904	10	214	1½	.....	.....	.....
Colonial Beach..	¼ mi. N.	Colonial Beach Hotel			.....	.....	.....	.....	.....	.....	.....
		(5 wells)		M	1904	12	212	1½	212	.....	.....
Colonial Beach..	½ mi. N.	Mrs. C. A. Eckstein...	Chas. Pfeil	O	1898	6	196	1¼	196	.....	.....
Colonial Beach..	1 mi. S.	J. C. Felch	Chas. Pfeil	M	1905	10	224	1½	.....	.....	.....
Colonial Beach..	½ mi. S.W.	E. Gouldman.....	E. Gouldman	O	1904	15	245	2	225	.....	60
Colonial Beach..											80
Colonial Beach..	near W	John Hammond	Chas. Pfeil	O	1903	6	200½	2	200½	.....	200
Colonial Beach..		T. B. Harrison		O	1896	12	200	1	.....	.....	.....

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
	Calvert	+35	4 3		63½		
		+30					Domestic and stock
	Calvert (?)	+22	2		67	Alkaline	Never used, no flow Drinking, stock, boats
Rock	Calvert (?)	+29	¾		63½	Alkaline	Domestic stock and medicinal
		+20					Never used, no flow
Sand	Calvert	flows	1			Soft	Abandoned House and stock
	Calvert		½-1		62-63		Household and stock
Gravel	St. Marys		3			Ferruginous	
	Calvert						Household and stock
Rock and sand	Calvert		2			Soft	Household and stock
Sand	Calvert		1½		63		
Sand	Calvert				61		
	Calvert		1			Soft	Canning factory
	Pamunkey						
	Pamunkey	+22					Domestic and stock
	Pamunkey		3½		62		No flow, not used
	Pamunkey		1¾		61		Drinking and public Hotel
Sand	Pamunkey					Soft	Domestic and stock
Sand	Pamunkey		2			Soft	Domestic and stock
	Calvert		8			Soft	General
	Calvert						Tomato cannery and domestic
	Calvert	+12	3				
	Calvert		1½			Sulphur	Domestic and stock
	Calvert	flows					
Rock cays 210- 230, sand	Pamunkey	+30	6			Soft	House and stock
	Pamunkey				61		Household
	Pamunkey		7/8		61		Household
	Pamunkey		¼				Hotel
	Pamunkey	flows	2			Soft	Household
	Pamunkey		5	15			All
	Pamunkey		½		61		Household
	Pamunkey		¼		61		Household
Thin rock at 220, chocolate col'd clay	Pamunkey	+19	3			Soft	Household
Sand	Pamunkey		4-1½		62¾		Ice manufacture
	Pamunkey		½		64½		Household

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
WESTMORELAND —Cont.											
Colonial Beach..	2 mi. SW	L. W. Jett	L. W. Jett.....	O	1901	15	230	1½	222	75	222
Colonial Beach..	W.	Dr. A. E. Johnson.....			1899	10	225				
Colonial Beach..	W.	D. Knowlton.....	C. Jones	O	1902	20	250				
Colonial Beach..	¼ mi. N.	M. E. Loeffler.....	E. Gouldman	O	1906	20	244	1¼	200		
Colonial Beach..	¼ mi. SW	Mutual Ice Co.....	R. Rude	D	1909	5	422	1½	415	220	
Colonial Beach..	S. W.	Maguinnis Estate	—Graves	M	1898	9	214	1½			
Colonial Beach..	2 mi. SW	O. L. Massey.....		M	1900		225	1½			
Colonial Beach..	near N.	A. Mensch	Chas. Pfeil	D		6	204	1¼	204		
Colonial Beach..	near	—Pierson	Chas. Pfeil	D	1897	8	208	1½			
Colonial Beach..	near N.	Reh & Ninde		O	1900	10	225	1	225		
Colonial Beach..	½ mi. W.	John Sebastian	E. Gouldman.....	D			80	1½			
Colonial Beach..	½ mi. NW	J. R. Sutton.....	Chas. Pfeil	O	1905	18	230	1½	230		
Colonial Beach..	1 mi. S.	J. M. Taylor.....	—Roane	O	1896	4	210	2			50
Colonial Beach..	N.	J. W. Thompson.....		O	1904	20	242	1¼	242		
Colonial Beach..	W.	Town	—Roane	M		11	225				
Colonial Beach..	1 mi. S.	Town		M	1902	8½	247	1½			
Colonial Beach..	near S.W.	F. W. Walcott.....	Johnson	O	1888	10	276(?)	1½	230	none	80
Colonial Beach..	S. W.	C. W. Welles.....	Chas. Pfeil	O	1904	8	214	1½	214	70	86
Colonial Beach..	½ mi. SW	C. W. Welles.....	Chas. Pfeil	O	1900	8	214	1½	214		
Erica	1 ½ mi. E.	N. T. Ames.....	Chas. Jones	O	1902	7	187	1½	187		100
Erica	1½ mi. SW	Paul Detrick.....		M	1900	13	327	1½			
Erica	near S.W.	E. T. Barnett.....	Chas. H. Jones.....	O	1903	15	335	3			
Hague	3 ½ mi. N.	G. F. Brown (3 wells)...	L. Rude	O	1894	8	247	2			247
Hinnom		J. B. Hall.....	Chas. H. Jones.....	O	1897	2	144	1½	144		44
Hinnom	near	Hardwick & Sanford....	Chas. H. Jones.....	O	1903	8	154	1½	144		
Kinsale	½ mi. N.E.	G. P. Bailey.....	G. P. Bailey.....	O	1894	8	238	1½	235		235
Kinsale		G. P. Bailey.....	Chas. H. Jones.....		1901	6	238	1½	235		40
Kinsale		G. P. Bailey.....	Chas. H. Jones.....		1903	6	238	1½	235		40
Kinsale	¼ mi. N.E.	Dameron & Courtney...	L. Rude	O	1893	4	275	1½			150
Kinsale	½ mi. N.E.	S. B. Hardwick.....		O	1892	6	245	1½			100
Kinsale	¾ mi. N.E.	V. B. Hardwick.....		O	1902	8	245	1½			40 220
Kinsale	1 mi. N.	Chas. Taylor.....	Chas. H. Jones.....	O	1903	7	260	1½	260	190	140
Maple Grove..	1 mi. E.	Floyd Omohundro.....	E. Gouldman	O	1905	60	300	1½			40
Meter		B. H. Bronson.....					240				
Meter	½ mi. W.	H. L. Shepard.....	Chas. H. Jones.....	O	1896	6	227	1			
Mount Holly...	½ mi. E.	S. J. Hopkins.....	Chas. H. Jones.....	O	1897	4	135	2	135		25
Mount Holly...	near	Nominie Packing Co....	Chas. H. Jones.....	O	1903	9	153	1½	153	144	50
Oak Grove.....	2 mi. S.W.	Andrew Flanner	Shaw & Roane.....	O	1897		664	1½	303		110
Oak Grove.....		Andrew Flanner		O			63	48			

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Sand	Pamunkey	+35			61		Household and public
	Pamunkey		1½		60½		Household
	Pamunkey		1½		62		Household
	Pamunkey	15	¾				Hotel
White sand	Potomac		6				Making ice
	Pamunkey	+15	1¼		64½	Soft, sulphur	Household
	Pamunkey					Soft, sulphur	Household
Rock	Pamunkey		2			Soft, sulphur	Hotel
	Pamunkey					Soft, sulphur	Flow stopped
	Pamunkey		½		61	Soft, sulphur	Hotel and store
	Pamunkey					Soft, sulphur	
	Pamunkey					Soft, sulphur	Flow stopped, not used
	Pamunkey	+12	1			Soft, sulphur	Household
	Pamunkey		½		63	Soft, sulphur	Household
	Pamunkey		1½		63	Soft, sulphur	Public
	Pamunkey		1½		61	Soft, sulphur	Public
	Pamunkey	+18					
Black sand	Pamunkey	+10	4			Soft, irony	Domestic and hotel
Red clay	Pamunkey	+14	¾		62	Soft, sulphur	Household
Clay	Pamunkey	+6	1			Soft	Household
Gravel	Pamunkey	+9	¾			Soft, sulphur	Household and stock
	Pamunkey		2¼		65	Soft	Household and stock
Sand	Pamunkey	+12				Irony	Household and stock
Rock at 200 feet	Pamunkey					Soft, sulphur	Household and stock
White sand	Chesapeake		1½		63¾		
	Chesapeake	+20	18			Soft	Canning factory
Rock	Chesapeake	+18	4				Steamboat and canning
	Chesapeake	+16	4		64		Canning factory and steamboat dock
	Chesapeake		4				
Sand	Chesapeake	+18	7			Soft	Canning factory and drinking
	Chesapeake	+18	4				Canning factory and drinking
Sand	Chesapeake	+15	8				Canning factory and drinking
Sand	Chesapeake		5		61	"Slightly hard"	Household and stock
White sand		+20					Not used, no flow
		flows					
Rock at 125 feet	Chesapeake	flows	1½		63	Soft, slightly sulphur	Domestic
						Soft, sulphur	Household and stock
Rock	Chesapeake	+18	2		63		
							No flow, never completed
	Chesapeake						Household

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

County and Postoffice	Direction and distance from Postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
WESTMORELAND											
—Cont.											
Oak Grove	2 mi. W.	W. D. Wirt.....	Chas. Pfeil	O	1894	23	190	2	190	.....	40
Potomac Mills..	4 mi. N. E.	James Muse.....	F. K. Walcott.....	M	1900	22	280	3	280	.....	....
YORK											
Grove	5 mi. S. W.	A. G. Harwood.....	H. E. Shimp.....	M	1903	30	429	2	429	none	60
Lackey	1 mi. N. E.	Mrs. K. Kirkwood.....	H. E. Shimp.....	M	1903	.....	450	1	450	300	....
Magruder	2 mi. N. E.	.....	.....	M	1890	2	226	1½	.....	.....	....
Messick	2 mi. N. W.	S. J. Marynham.....	J. W. T. Robertson ..	.....	1904	.....	90	.....	.....	.....	....
Oaktree	3 mi. E.	Edward Maynard.....	S. H. Felterholf.....	D	1905	11	367	2	.....	.....	....
Yorktown	3 mi. N. W.	G. B. Donnelly.....	H. E. Shimp and S. H. Felterholf	D	1903	2	429	2	.....	70	....
Yorktown	5 mi. N. W.	—Squires	S. H. Felterholf.....	D	1906	6	358	2	.....	.....	....
Yorktown .....	.....	Am. Cem. & Eng. Co....	H. A. McTavish.....	M	1909	3	750	3	750	.....	....
Williamsburg ...	4 mi. N.	.....	S. H. Felterholf.....	.....	1906	.....	408	2	.....	.....	....

TABLE 5 (Continued)—Data of wells in Coastal Plain Province of Virginia.

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
.....	Pamunkey	flows	1/8	.....	.....	Soft	Domestic and stock
Rock at 80 ft. gravel	Pamunkey	flows	1/2	.....	.....	Soft	Domestic and stock
Gravel	Pamunkey	+20	.....	.....	.....	Alkaline	Domestic, boiler
Gravel	Pamunkey .....	.....	4 1/2	.....	.....	Soft, alkaline	Domestic and stock
.....	Chesapeake	+20	20	.....	.....	Sulphur	Domestic
.....	Pamunkey	+25	1 1/2	.....	.....	.....	Household
Green rock	Pamunkey	+38	4	.....	.....	.....	Household and stock
.....	.....	+28	3	.....	.....	.....	Household and stock
.....	.....	+10	1	.....	.....	"Good" .....	.....
.....	.....	+25	10-1	.....	.....	.....	Drinking, &c.

TABLE 6—Analyses and field assays (F) of water from springs.

County and locality	Name of Spring	Owner	Source	Turbidity	Total solids	Organic and volatile matter	Silica (SiO ₂)	Iron and aluminum oxides (Fe ₂ O ₃ +Al ₂ O ₃)	Iron (Fe)
ALEXANDRIA									
Ballston	Powhatan		Granite.....		38.0		12.		.2
Glencarlyn	Erup Mineral	H. H. Young	Gravel.....		47.8	9.0			.1
CHARLES CITY									
Oldfield		A. M. Wheeler.....	Sand		73.17		17.4		.5
Oldfield		A. M. Wheeler.....	Sand		61.08		19.65		.87
CHESTERFIELD									
Bon Air.....	Beaufont	Beaufont Lithia Spring Water Co....	Granite.....		63.		16.		.25
Buckhead Springs.....	Buckhead Chloride Lithia..	T. S. Wheelwright..	Sand		43.		7.4		.1
Manchester	Bellfont Lithia		Granite.....		45.		14.		1.
Manchester	Fonticello Lithia	W. G. Taylor	Granite.....		46.		14.		1.6
Manchester	Lion Lithia	Virginia Lithia Springs Co.	Sand		28.1		10.		.11
Temples	Campfield Lithia	Campfield Lithia Water Co.			28.		5.3		.3
Swansboro	Holly Lithia	Holly Springs Co.	Sand and gravel		35.6		10.7		.29
Swansboro	Holly Lithia	Holly Springs Co.	Sand and gravel		35.4		11.2		.35
Wiseville	Rocky Run Lithia	David Adkins							1.1
ESSEX									
Meade	Sulphur	Chas. Tombs	Sand and iron crusts	.0					1.5
Meade	Sulphur	Chas. Tombs	Sand	.0					tr.
GLOUCESTER									
James Store		County	Marl	.0					.0
HANOVER									
Hanover Station		R. F. & P. Ry.	Sand	.0					
Ellerson		B. A. Taliaferro.....	Sand		19.		6.2		.08
HENRICO									
Barton Heights		Town	Marl and sand..	.0	106.	42.			.03
East Richmond.....	Como Lithia	I. J. Hawkes	Sand and gravel		34.	tr.	5.4		.1
Elko		R. W. Swift	Sand	.0					tr.
Richmond		County	Sand	.0					
Richmond		Home Brewing Co. ..	Gravel		124.	16.			tr.

^aAmmonium (NH₄), .069.^bAmmonium (NH₄), .016.^cAmmonium (NH₄), .013.^dBarium (Ba), .02.^eBarium (Ba), .008.^fBarium (Ba), trace.

TABLE 6 (Continued)—Analyses and field assays (F) of water from springs.

Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Arsenate radicle (AsO ₄)	Phosphate radicle (PO ₄)	Sulphate radicle (SO ₄)	Carbonate radicle (CO ₃)	Bicarbonate radicle (HCO ₃)	Nitrate radicle (NO ₃)	Iodine (I)	Bromine (Br)	Chlorine (Cl)	Total hardness as CaCO ₂	Date	Analyst
.....	0.	1.6	1.	....	3.7	1.2	0. ^a	0.	0.	1.2	.....	12.	1.55	tr.	0	3.8	.....	1905	J. K. Haywood
.....	.....	2.9	1.8	....	5.7	1.5	tr.	.....	.....	3.3	.....	9.1	.....	.....	.....	6.3	.....	1905	J. K. Haywood
.....	.....	4.5	1.5	....	10.45	3.18	^b	.....	.....	2.57	.....	11.82	8.85	.....	.....	10.61	.....	1908	.....
.....	.....	2.25	.8	....	9.2	3.	^c	.....	.....	2.10	.....	10.8	3.32	.....	.....	7.40	.....	1908	.....
8.4	tr.	1.4	1.	....	4.	2.1	.07	tr.	0.04	1.3	.....	15.	.....	.06	tr.	5.2	.....	.....	Henry Froehling
.53	.....	1.4	2.5	^d	3.6	2.3	.001	ft. tr.	.009	.72	.....	3.1	8.8	.....	11.	.....	.....	1904	Froehling & Robertson
.....	.....	1.9	.4	....	3.8	2.9	.03	.....	.....	10.	.....	5.3	.....	.....	.....	5.8	.....	.....	W. H. Taylor
.07	tr.	2.	.61	....	3.5	1.5	.08	tr.	.04	2.5	.....	13.	.....	.....	.....	5.4	.....	.....	Henry Froehling
.78	.022	1.0	.4	....	2.98	1.2	.011	.039	.035	4.1	.....	3.9	.....	.11	tr.	3.6	.....	.....	Froehling & Robertson
.11	tr.	.8	.9	^f	3.2	1.9	.05	tr.	.03	2.4	.....	8.	0.0	tr.	tr.	5.2	.....	.....	N. B. Tucker
.76	.....	1.86	.47	....	2.8	1.4	.09	tr.	tr.	2.47	.....	10.7	.....	tr.	tr.	2.8	.....	1894	C. H. Chalkey
.8	.....	1.35	.35	^e	4.6	1.	.083	.....	.03	4.3	.....	4.8	2.7	tr.	.....	4.4	.....	1907	Froehling and Robertson
.....	.....	40.	.46	.....	1.1	1.6	.07	.....	.....	6.3	1.2	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	little	.....	.....	.....	.....	.....	.....	.....	tr.	0	24.	.....	.....	4.	.....	44.	1906	S. Sanford (F)
.....	.....	0.(?)	.....	.....	.....	.....	.....	.....	.....	>30	0	10.	.....	.....	4.	.....	28.	1906	S. Sanford (F)
.....	.....	bauch	.....	.....	.....	.....	.....	.....	.....	>30	0.	180.	.....	.....	.....	8.8	75.	1906	S. Sanford (F)
.11	.02	.7	.3	....	2.2	.8	.01	tr.	.03	2.3	.....	15.	.....	tr.	.....	9.	17.	1906	S. Sanford (F)
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.7	.....	.....	3.1	.....	.....	.....	Henry Froehling
.53	.....	.86	1.1	....	4.7	2.1	.07	tr.	.....	.41	.....	.....	.44	.....	.....	16.5	32.5	1905	E. C. Levy
.....	.....	mod.	.....	.....	.....	.....	.....	.....	.....	tr.	.....	7.9	.....	.39	tr.	10	.....	1892	Henry Froehling
.....	.....	0	.....	.....	.....	.....	.....	.....	.....	0	.....	58.	.....	.....	.....	3.	58.	1906	S. Sanford (F)
.....	.....	8.6	6.	.....	.....	.....	.....	.....	.....	6.5	.....	12.	.....	.....	.....	5.5	48.	1906	S. Sanford (F)
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	tr.	.....	.....	.....	37.	46.	1907	First Scientific Station for the Art of Brewing

TABLE 6 (Continued)—Analyses and field assays (F) of water from springs.

County and locality	Name of Spring	Owner	Source	Turbidity	Total solids	Organic and volatile matter	Silica (SiO ₂)	Iron and aluminum oxides (Fe ₂ O ₃ +Al ₂ O ₃)	Iron (Fe)
JAMES CITY									
Williamsburg .....	.....	Mrs. R. M. Smith....	Marl.....	.0	.....	.....	.....	.....	.0
KING GEORGE									
Hickory Fork.....	.....	.....	Sand .....	.....	.....	.....	.....	.....	tr.
KING WILLIAM									
Enfield .....	.....	G. W. Scott	Sand	.0	.....	.....	.....	.....	.4
NEW KENT									
Whitehouse	Belmont Lithia	R. E. Richardson....	Marl.....	.....	221.	.....	33.	.....	4.7
NORFOLK									
.....	White Oak Mineral.....	.....	.....	.....	146.	.....	5.4	.....	tr.
.....	Landale Mineral Spring.....	.....	Sand .....	.....	87.	.....	5.3	.....	.06
PRINCE GEORGE									
Blair .....	.....	David Dunlop .....	.....	.0	.....	.....	.....	.....	tr.
Warwick Church .....	.....	Warwick Church	Sand	.0	.....	.....	.....	.....	tr.
PRINCESS ANNE									
Waterway	Diamond .....	.....	Sand .....	.....	.....	.....	.....	.....	.....
SPOTTSYLVANIA									
Fredericksburg .....	.....	Aqueduct Co.	Sand and gravel .....	.....	.....	.....	.....	.....	.....
Fredericksburg	Gunnery	City	Sand and gravel	.0	.....	.....	.....	.....	tr.
Fredericksburg	Mint	City	Sand and gravel	tr.	.....	.....	.....	.....	.....
Fredericksburg	Silk Mill .....	.....	.....	.0	157.	.....	.....	.....	.08
SURRY									
Claremont .....	.....	E. S. Collins.....	Marl.....	.0	207.	60.	39.	.....	.04
Claremont	Trepho Lithia	E. E. Harry.....	Sand	.0	.....	.....	.....	.....	1.5
Claremont.....	Trepho Lithia	E. E. Harry.....	Sand .....	.....	573.	.....	34.	.....	2.9
SUSSEX									
Waverly	Cappahaunk .....	.....	Marl.....	.0	.....	.....	.....	.....	3.
Waverly	Cappahaunk .....	.....	Marl.....	.....	293.	.....	23.	.....	.7
WESTMORELAND									
Kinsale .....	.....	Chas. Taylor	Sand	.0	.....	.....	.....	.....	.....

Also contains Barium (Ba), .15; Strontium (Sr), .10; Zinc (Zn), faint trace.

TABLE 6 (Continued)—Analyses and field assays (F) of water from springs.

Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Arsenate radicle (AsO ₄)	Phosphate radicle (PO ₄)	Sulphate radicle (SO ₄)	Carbonate radicle (CO ₃)	Bicarbonate radicle (HCO ₃)	Nitrate radicle (NO ₃)	Iodine (I)	Bromine (Br)	Chlorine (Cl)	Total hardness as CaCO ₂	Date	Analyst
.....	much	.....	.....	.....	.....	.....	.....	.....	.....	>30	.....	160.	.....	.....	9.5	140.	1906	S. Sanford (F)	
.....	little	.....	.....	.....	.....	.....	.....	.....	.....	tr.	.....	30.	.....	.....	10.	.....	1906	S. Sanford (F)	
.....	little	.....	.....	.....	.....	.....	.....	.....	.....	tr.	0.	18.	.....	.....	7.6	31.	1906	S. Sanford (F)	
.053	.16	34.	1.8	.....	5.5	3.4	.01	.....	.26	3.5	.....	132.	tr.	.....	2.7	.....	.....	W. H. Taylor	
.....	21.	2.8	.....	14.	3.6	.....	.....	.....	29.	.....	55.	.....	.....	.....	15.	.....	.....	W. H. Taylor	
.18	tr.	5.8	2.5	.....	14.	1.3	.01	tr.	.....	28	.....	9.2	5.5	.009	tr.	13.	.....	S. Sanford (F)	
.....	little	.....	.....	.....	.....	.....	.....	.....	.....	>30	.....	42.	.....	.....	3.1	55.	1906	S. Sanford (F)	
.....	little	.....	.....	.....	.....	.....	.....	.....	.....	>30	.....	42.	.....	.....	4.5	33.	1906	S. Sanford (F)	
.....																			
.....	little	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	17	.....	.....	9.	10.	1906	S. Sanford (F)	
.....	little	.....	.....	.....	.....	.....	.....	.....	.....	>30	0	50	.....	.....	27	.....	1906	S. Sanford (F)	
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	23	.....	.....	35.	18	1906	S. Sanford (F)	
.....	6.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	29.	.....	.....	.....	24.	1905	E. C. Levy	
.....	35.	7.6	.....	23.	.....	.....	.....	.....	.....	17.	10.	155.	.9	.....	6.6	.....	1906	E. B. Dole	
.....	some	.....	.....	.....	.....	.....	.....	.....	.....	>30	0.	180.	.....	.....	6.	140	1906	S. Sanford (F)	
1.95	2.9	3.2	.....	11.	2.1	.03	.....	.....	.....	3.8	.....	395.	.....	.....	3.5	.....	1907	J. B. Weems	
.....	much	.....	.....	.....	.....	.....	.....	.....	.....	>30	.....	305	.....	.....	7.5	220	1906	S. Sanford (F)	
9.9	tr.	93.	1.5 ^a	.....	5.4	2.9	.19	.034	.12	>30	.....	.....	.....	tr.	tr.	11.	.....	.....	
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.6	143.	.....	.....	.....	.....	.....	.....	Froehling & Robinson	
.....	0. (?)	.....	.....	.....	.....	.....	.....	.....	.....	>30	.....	32.	.....	.....	14.	13.	1906	S. Sanford (F)	

TABLE 7—Analyses and field assays (F) of well water from Columbia formations.

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO ₂)	Iron and aluminum oxides (Fe ₂ O ₃ +Al ₂ O ₃)
Accomac							
Accomac	County	dug	26				
Accomac	G. L. Doughty	driven	34				
Accomac	B. T. Melson	drilled	50				
Belinda	M. E. Hall	drilled	68				
Chincoteague	D. J. Whealton	driven	14				
Fox Island	W. Ellinger	driven	32				
Fox Island	W. Ellinger	driven	32				
Franklin City	James Chapman	driven	70				
Franklin City	N. Y. P. & N. R. R.	driven	80	250.			
Greenbackville	J. T. Sharpley	driven	40				
Greenbackville	Elihu Tull	driven	34				
Hallwood	N. Y. P. & N. R. R.					14.	
Nandua	J. R. Henderson	drilled					
Nandua	A. T. L. Kusian	drilled	75				
New Church							
New Church							
Onancock	Town	driven					
Onancock	Town	dug and driven					
Onancock	M. L. Hurst	driven	36				
Pungoteague	S. T. Taylor	driven	62				
Tasley	N. Y. P. & N. R. R.	dug	12	71			
Tasley	N. Y. P. & N. R. R.	driven		112.		6.8	
Wachapreague	W. E. Brittingham	driven	12				
CAROLINE							
Bowling Green	Gill	dug	35				
Bowling Green	Town	dug					
Bowling Green	R. P. Vincent	dug					
Bowling Green	Dr. A. Webb	dug					
Delos		dug	20				
Messaponax		dug	22				
Port Royal	Arkins	dug	25				
CHARLES CITY							
Charles City	Mrs. Major	dug	40				
Shirley	H. I. Saunders	driven	30				
CHESTERFIELD							
Manchester	Chesterfield Laundry						
ELIZABETH CITY							
Hampton	Hampton Institute						
Hampton	Hampton Institute			524.			
Hampton	Hampton Mfg. Co.	dug					
Hampton	Hampton Roads Ry. & Elect. Co.	dug					
Hampton	City	dug	22				
ESSEX							
Center Cross		dug	22				
Tappahannock	Jas. Jackson	driven	13				
GLOUCESTER							
Achilles							
Bridges	Thos. Bridges	driven	12				

TABLE 7 (Continued)—Analyses and field assays (F) of well water from Columbia formations.

Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO ₃)	Bicarbonate radicle (HCO ₃)	Sulphate radicle (SO ₄)	Nitrate radicle (NO ₃)	Chlorine (Cl)	Total hardness as CaCO ₃	Date	Analyst
tr.								0.	25.	tr.		15.	15.	1906	S. Sanford (F)
tr.								0.	130.	tr.			91.	1906	S. Sanford (F)
1.5(?)			mod.					0.	11.	tr.		5.5	25.	1906	S. Sanford (F)
			0.(?)					0.	180.	much		630.	440.	1906	S. Sanford (F)
2.			much					0.	240.	47.		210.	180.	1906	S. Sanford (F)
10.									340.			320.	18.	1907	S. Sanford (F)
3.5			much					0.	330.	>30.		740.	300.	1907	S. Sanford (F)
.8(?)			little					0.	230.	tr.		60.	85.	1906	S. Sanford (F)
little												14.6		1893	
tr.			little					0.	34.	tr.		9.	20.	1906	S. Sanford (F)
1.5			much					0.	45.	tr.		20.		1906	S. Sanford (F)
1.2		.9	6.	63.					17.	10.		tr.			Baldwin Locomotive Works
.5			little						42.	>30.		6.5	43.	1906	S. Sanford (F)
1.			much						180.	0.		30.	110.	1906	S. Sanford (F)
0.			113.					0.	83.	tr.		49.	102.	1906	H. N. Parker (F)
0.			much						100.	>30.		47.	55.	1906	S. Sanford (F)
1.			much						110.	>30.		9.5	58.	1906	S. Sanford (F)
2.(?)			little						62.	tr.		8.	50.	1906	S. Sanford (F)
0.			some	little				0.		some		16.		1899	C. B. Dudley
1.2		.9	8.6	66.					17.	10.		1.7			Baldwin Locomotive Works
tr.			mod.						180.	15.		110.	200.	1906	S. Sanford (F)
			little						17.	tr.		73.		1906	S. Sanford (F)
tr.			mod.					0.	11.	0.		39.	60.	1906	S. Sanford (F)
.5			much					0.	37.	little		28.	90.	1906	S. Sanford (F)
1.8			mod.						37.	tr.		80.	60.	1906	S. Sanford (F)
1.5													50.		S. Sanford (F)
			little					0.	19.			14.	52.	1906	S. Sanford (F)
			much							>30.		120(?)	115.	1906	S. Sanford (F)
0.			little					0.	15.	0.		24.	38.	1906	S. Sanford (F)
tr.			little					0.	20.	0.		8.	35.	1906	S. Sanford (F)
														1906	H. Bentley Smith Co.
			188.	16.5						32.		113.	38.		W. S. Sweetser
0.			some	tr.				some		some	24.	85.		1902	C. B. Dudley
														1904	H. Bentley Smith Co.
tr.			much						160.	tr.		87.	180.	1906	S. Sanford (F)
.5									23.	tr.		15.	21.	1906	S. Sanford (F)
1.5			mod.						300.	62.		54.	76.	1906	S. Sanford (F)
tr.			0.						12.	0.		11.	18.	1906	S. Sanford (F)

TABLE 7 (Continued).—Analyses and field assays (F) of well water from Columbia formations.

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO ₂)	Iron and aluminum oxides (Fe ₂ O ₃ +Al ₂ O ₃)
GREENVILLE Emporia	Emporia Mfg. Co.	bored and driven	22				
HANOVER Ellerson	R. L. Acree.	dug.	42				
Hanover C. H.	County	dug.	25				
HENRICO Ginter Park	S. H. Hawes.	dug.	32	62.	.17	8.0	
Richmond	Lewis Ginter L. & I. Co.	dug.	27				
Richmond	Roseneegk Brewing Co.	dug.	10	110.	40.	19.	
ISLE OF WIGHT Moonlight	Dr. Wells	dug.	10				
JAMES CITY Williamsburg ^a	H. Johnson	dug.	35				
KING GEORGE King George	County	dug.	30				
Passapatanzy		dug.	20				
KING AND QUEEN Cumnor	C. C. Vaughan	dug.	30				
MATHEWS Mathew C. H.		dug.	10				
MIDDLESEX Churchview		dug.	22				
NORFOLK Berkley	Portsmouth, Berkeley & Suffolk Water Co.						
Berkley	Portsmouth, Berkeley & Suffolk Water Co.	driven	20-35				
Buella ^a	Pocomoke Guano Co.	driven	86	600.	301.		
Port Norfolk	Air Line Mfg. Co.	driven		170.	53.	7.7	
Port Norfolk	Air Line Mfg. Co.	driven	38	275. ^b	7.7	44.	2.9
Port Norfolk	Portsmouth & Norfolk Tract. Co.	driven	16-50	210.	72.	14.	7.
Port Norfolk	Seaboard Air Line R. R.	driven	60	280.	15.	40.	2.9
Port Norfolk	Seaboard Air Line R. R.	driven	old wells	275. ^b	7.7	44.	.34
Port Norfolk	Seaboard Air Line R. R.	driven	60	218.	8.	42.	3.
Port Norfolk	Seaboard Air Line R. R.	driven	new wells	^b	10.	43.	tr.
Portsmouth	United States	driven	35	236.	85.	9.9	5.8
Norfolk	Imperial Co.			1,294.	24.	34.	
NORTHAMPTON Cape Charles	Heckle & Kellogg	driven		195.			
Cape Charles	N. Y. P. & N. R. R.	drilled	90			20.	
Cape Charles	N. Y. P. & N. R. R.	drilled	18	251.		17.	
Cape Charles	N. Y. P. & N. R. R.	drilled	12	226.			
Cape Charles	N. Y. P. & N. R. R.	drilled	90			21.	5.1
Cape Charles	N. Y. P. & N. R. R.	drilled	97	218.			

^aWater may come from Chesapeake (Miocene) sand.^bSample taken after prolonged pumping.

TABLE 7 (Continued)—Analyses and field assays (F) of well water from Columbia formations.

Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO ₂)	Bicarbonate radicle (HCO ₃)	Sulphate radicle (SO ₄)	Nitrate radicle (NO ₃)	Chlorine (Cl)	Total hardness as CaCO ₃	Date	Analyst
0.5 tr.		little	.....	.....	.....	.....	.....	0.	16.	0.	.....	6.	21.	1904	H. Bentley Smith Co.
.....		little	.....	.....	.....	.....	.....	0.	22.	tr.	.....	31.	41.	1906	S. Sanford (F)
.....														1906	S. Sanford (F)
1.7 tr.		5.4	4.6	.9	tr.	.....	.....	1.4	.....	tr.	31.	7.	.....	1906	Froehling & Robertson
.....		0.(?)	.....	.....	.....	.....	.....	0.	12.	>30.	.....	8.	18.	1906	S. Sanford (F)
.....		5.4	.56	13.	.....	.....	.....	.....	.....	.....	.....	31.	.....	1904	H. Bentley Smith Co.
2.(?)		little	.....	.....	.....	.....	.....	.....	14.	tr.	.....	11.	.....	1906	S. Sanford (F)
0.		much	.....	.....	.....	.....	.....	.....	180.	tr.	.....	46.	.....	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	0.	32.	0.	.....	.....	.....	1906	S. Sanford (F)
tr.		little	.....	.....	.....	.....	.....	0.	7.3	.....	.....	14.	8.	1906	S. Sanford (F)
.....															
tr.		little	.....	.....	.....	.....	.....	0.	23.	little	.....	25.	32.	1906	S. Sanford (F)
.....															
tr.		mod.	.....	.....	.....	.....	.....	.....	40.	mod.	.....	50.	75.	1906	S. Sanford (F)
.....															
tr.		little	.....	.....	.....	.....	.....	0.	24.	0.	.....	30.	23.	1906	S. Sanford (F)
.....															
.10								12.	.....	20.	.....	17.	35.	.....	.....
tr.									25.	tr.	.....	15.	35.	1906	S. Sanford (F)
.....		74.	31.	50.	.....	.....	.....	292.	.....	.....	.....	78.	.....	.....	Sparrows Point Boiler Compound Co.
2.5(?)		27.	4.3	7.	.....	.....	.....	28.	.....	18.	.....	24.	.....	1905	H. Bentley Smith Co.
.....		little	.....	.....	.....	.....	.....	.....	64.	little	.....	28.	56.	1906	S. Sanford (F)
.....		21.	7.2	.....	.....	.....	.....	54.	.....	49.	.....	.....	.....	1906	Sparrows Point Boiler Compound Co.
.....		35.	6.3	45.	.....	.....	.....	78.	.....	7.5	tr.	50.	.....	1906	Froehling & Robertson
.....		32.	6.	49.	.....	.....	.....	83.	.....	4.8	tr.	48.	.....	1906	Froehling & Robertson
.....		38.	6.9	18.	.....	.....	.....	73.	.....	2.3	tr.	26.	.....	1906	Froehling & Robertson
.....															
.....		34.	8.3	18.	.....	.....	.....	73.	.....	3.2	tr.	25.	.....	1906	Froehling & Robertson
.....		36.	3.4	.....	.....	.....	.....	31.	.....	32.	.....	.....	.....	1906	Sparrows Point Boiler Compound Co.
1.3		11, 410.	42.	310.	.....	.....	.....	187.	.....	8.1	tr.	574.	.....	1906	Froehling & Robertson
.....															
1.2		.9	50.	67.	.....	.....	.....	.....	350.	0.	.....	48.	.....	1905	York Mfg. Co.
3.6		27.	31.	55.	.....	.....	.....	.....	124.	3.4	.....	1.7	.....	.....	.....
.....										14.	.....	3.4	.....	.....	Baldwin Locomotive Works
.....			much	some	.....	.....	.....	.....	.....	much	.....	70	35.	1899	C. B. Dudley
.....		6.5	2.2	.....	.....	.....	.....	.....	.....	5.3	.....	20.	81.	.....	Baldwin Locomotive Works
.....		much	little	.....	.....	.....	.....	much	.....	little	.....	21.	.....	1899	C. B. Dudley

TABLE 7 (Continued)—Analyses and field assays (F) of well water from Columbia formations.

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO ₂)	Iron and aluminum oxides (Fe ₂ O ₃ +Al ₂ O ₃)
NORTHAMPTON—Cont.							
Eastville	N. Y. P. & N. R. R. ....	.....	10	190.	.....	8.5	.....
Eastville	N. Y. P. & N. R. R. ....	.....	40	.....	.....	.....	.....
Eastville	County	driven	12	144.	.....	.....	62.
Exmore	N. Y. P. & N. R. R. ....	.....	18	.....	.....	22.	4.8
Exmore	N. Y. P. & N. R. R.	driven	12(?)	87.3	.....	8.5	.....
Exmore	N. Y. P. & N. R. R.	driven	30	.....	.....	33.	8.2
NORTHUMBERLAND							
Heatsville	J. E. Nelms	dug	45	.....	.....	.....	.....
PRINCESS ANNE							
Waterway	Norfolk County Waterworks.....	driven	30	115.	51.	.....	.....
Virginia Beach	Walker	driven	17	.....	.....	.....	.....
Waterway	Norfolk County Waterworks.....	driven .....	.....	.....	.....	.....	.....
PRINCE GEORGE							
Claremont .....	.....	.....	.....	.....	.....	.....	.....
Garysville	H. C. Browning	dug	25	.....	.....	.....	.....
SURREY							
Bacon's Castle	M. Bell	dug	28	.....	.....	.....	.....
Dendron	E. Jones	driven	25	.....	.....	.....	.....
Homewood	W. F. Madder	dug	30	.....	.....	.....	.....
SUSSEX							
Wakefield	Baine Peanut Co.	dug	12	389.	180.	10.	.....
Wakefield	E. W. Brittle	driven	20	.....	.....	.....	.....
Wakefield	S. Parr	dug	16	.....	.....	.....	.....
Waverly	Waverly Peanut Co.	dug	16	65.	4.4	10.	.....
Waverly	J. D. Gray	driven	35	.....	.....	.....	.....
WESTMORELAND							
Kinsale	Hotel	dug .....	.....	.....	.....	.....	.....
Leedstown	Jas. Baxter	dug	20	.....	.....	.....	.....
Oak Grove	A. Flanner	dug	63	.....	.....	.....	.....
Potomac Mills	John Barrack	dug	27	.....	.....	.....	.....

TABLE 7 (Continued)—Analyses and field assays (F) of well water from Columbia formations.

Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO ₃)	Bicarbonate radicle (HCO ₃)	Sulphate radicle (SO ₄)	Nitrate radicle (NO ₃)	Chlorine (Cl)	Total hardness as CaCO ₃	Date	Analyst
1.2		.9	17.	54.	.....	.....	.....	77.	.....	8.5	.....	1.7	.....	.....	Baldwin Locomotive Works
little			some	much	.....	.....	.....	.....	.....	much	.....	35.	.....	1899	C. B. Dudley
0.			little	.....	.....	.....	.....	13.	.....	55.	.....	40.	67.	1906	S. Sanford (F)
much			some	much	.....	.....	.....	.....	.....	much	.....	43.	.....	1899	C. B. Dudley
.....			3.1	1.7	.....	.....	.....	.....	.....	3.8	.....	14.	25.	.....	.....
1.2		.9	6.	52.	.....	.....	.....	.....	.....	17.	.....	1.7	.....	.....	Baldwin Locomotive Works
.....			4.8	3.	.....	.....	.....	.....	.....	7.8	.....	13.	34.	.....	Baldwin Locomotive Works
.....								0.	30.	.....	.....	30.	70.	1906	S. Sanford (F)
.....											.75	8.	128.	1907	Booth, Garrett & Blair
tr.			little	.....	.....	.....	.....	26.	.....	>30.	.....	74.	50.	1906	S. Sanford (F)
tr.			little	.....	.....	.....	.....	8.	.....	>30.	.....	17.	42.	1906	S. Sanford (F)
0.			much	.....	.....	.....	.....	0.	110.?	0.	.....	11.	97.	1906	S. Sanford (F)
4.5(?)								100.	.....	>30.	.....	11.	55.	1906	S. Sanford (F)
.....			mod.	.....	.....	.....	.....	0.	23.	0.	.....	95(?)	70.	1906	S. Sanford (F)
.....			0.(?)	.....	.....	.....	.....	12.	.....	0.	.....	5.	41.	1906	S. Sanford (F)
.5			little	.....	.....	.....	.....	23.	.....	0.	.....	10.	38.	1906	S. Sanford (F)
.....			21.	.....	.....	.....	.....	24.	.....	11.	.....	93.	.....	1904	H. Bentley Smith Co.
.....			little	.....	.....	.....	.....	81.	.....	0.	.....	22.	55.	1906	S. Sanford (F)
tr.			0.(?)	.....	.....	.....	.....	14.	.....	0.	.....	22.	48.	1906	S. Sanford (F)
.....			10.	2.2	6.1	.....	.....	10.	.....	2.1	.....	20.	.....	1904	H. Bentley Smith Co.
tr.			little	.....	.....	.....	.....	0.	16.	0.	.....	12.	11.	1906	S. Sanford (F)
.....								0.	35.	.....	.....	35.	37.	1906	S. Sanford (F)
tr.			much	.....	.....	.....	.....	0.	62.	>30.	.....	20.	.....	1906	S. Sanford (F)
tr.			much	.....	.....	.....	.....	0.	21.	much	.....	31.	42.	1906	S. Sanford (F)
tr.			little	.....	.....	.....	.....	31.	.....	.....	.....	26.	13.	.....	S. Sanford (F)

TABLE 8—Analyses and field assays (F) of well water from Chesapeake formations.

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO ₂)	Iron and aluminum oxides (Fe ₂ O ₃ +Al ₂ O ₃)	Iron (Fe)
ACCOMAC								
Accomac ^a	B. T. Gunter	drilled	122.					2.
Accomac ^a	L. L. Tiffany	drilled	100.					tr.
Cashville ^a	Susan A. Tiffany	drilled	100.					tr.
Franklin City ^a		drilled	80.	250.				little
Harborton ^a	Allen & Lennau	drilled	140.					tr.
Pungoteague	S. W. Ames	drilled	210.	250.		45.		.1
CHARLES CITY								
Malvern Hill ^b	G. M. Gill	bored	70.					1.
Wilcox Wharf ^b	T. W. Hubbard	dug	43.	333.	3.1	34.		.75
ESSEX								
Bowler's Wharf	Donaldson & Schultz	drilled						
Bowler's Wharf	Claybrooke & McNeal Packing Co.	drilled	165.					tr.
Center Cross	C. F. Kriete	drilled	190.					tr.
Tappahannock	B. B. Broekenbrough	drilled	272.					tr.
Tappahannock	R. T. Cauthorn	drilled	275.	494.	48.			
Ware's Wharf	W. L. Ware	drilled	170.					tr.
GLOUCESTER								
Allmondsville	W. W. Allmond	drilled	270.					0.
Freeport	E. C. Farinholt	drilled	330.					.8
Freeport	R. H. Farinholt	drilled	338.					
Gloucester C. H.	Town	dug	30.					tr.
HENRICO								
Elko	E. J. Furman	driven	35.					1.
ISLE OF WIGHT								
Day's Point	J. A. Morgart	drilled	383.	434.		12.		.19
Shoalbay	Dr. Wm. D. Turner	drilled	226.	786.	15.	18.		.81
Smithfield	Smithfield Mineral Water Co.	drilled	330.	566.	.94	10.5		.22
Zuni	Town	drilled	161.					tr.
Zuni		drilled				16.2		.28
JAMES CITY								
Croaker	Wilbur H. Davis	drilled	200.	521.		21.		
Jamestown	C. F. Ayers	drilled	300.					tr.
Jamestown	Association for the Preservation of Virginia Antiquities	drilled	267.					tr.
Williamsburg	Marshall Estate	drilled	285.	523.		21.		tr.
Williamsburg	Galba Vaiden	drilled	276.	662.	10.			
Williamsburg	Mrs. R. M. Smith	drilled		185.		1.1		
Williamsburg	Mrs. R. M. Smith	drilled						3.0
Williamsburg	Eastern State Hospital	drilled	286.	553.		28.		tr.
KING GEORGE								
King George	Edward Hunter	dug	45.					tr.
KING WILLIAM								
West Point	Denmead Bros.	drilled	105.					tr.
West Point	Southern Railway	drilled	165.	927.		25.		.11
KING AND QUEEN								
Chain Ferry	Wm. Blake	drilled	165.					tr.
LANCASTER								
Irvington	W. A. Dameron & Bro.	drilled	330.					tr.

^aMay be in Columbia beds.^bSource of main supply uncertain.^cAlso ammonium radicle (NH₄), .39; borate radicle (B₂O₇), trace.^dBiborate radicle (B₄O₇), 3.5^eAmmonium radicle (NH₄), 9.7; borate radicle (B₂O₇), trace.

TABLE 8 (Continued)—Analyses and field assays (F) of well water from Chesapeake formations.

Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO ₃)	Bicarbonate radicle (HCO ₃)	Sulphate radicle (SO ₄)	Phosphate radicle (PO ₄)	Nitrate radicle (NO ₃)	Bromine (Br)	Iodine (I)	Chlorine (Cl)	Total hardness as CaCO ₃	Date	Analyst
.....	much	.....	.....	.....	.....	.....	140.	140.	tr.	.....	.....	.....	.....	12.	91.	1906	S. Sanford (F)
.....	much	.....	.....	.....	.....	.....	0. 124.	0. 124.	0.	.....	.....	.....	.....	11.	87.	1906	S. Sanford (F)
.....	much	.....	.....	.....	.....	.....	0. 170.	0. 170.	0.	.....	.....	.....	.....	11.	65.	1906	S. Sanford (F)
.....	much	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	14.6	.....	1893	C. B. Dudley
.....	some	.....	some	.....	.....	.....	0. 90.	0. 90.	.....	.....	.....	.....	.....	38.	56.	.....	S. Sanford (F)
25.	11.	32.	14.	.....	.....	.....	0. 218.	0. 218.	1.6	3.6	.....	.....	.....	12.	.....	1906	R. B. Dole
.....	tr.	.....	.....	.....	.....	.....	115.	115.	0.	.....	.....	.....	.....	27.	35.	1906	S. Sanford (F)
.5	2.5	.5	122.	.....	.....	tr.	313.	313.	7.7	.1	.....	.....	.....	4.3	.....	1906	R. B. Dole
.....	.....	.....	.....	.....	.....	.....	0. 200.	0. 200.	>25.	.....	.....	.....	.....	8.6	56.	1906	S. Sanford (F)
.....	mod.	.....	.....	.....	.....	.....	0. 150.	0. 150.	tr.	.....	.....	.....	.....	4.2	50.	1906	S. Sanford (F)
.....	mod.	.....	.....	.....	.....	.....	0. 205.	0. 205.	.....	.....	.....	.....	.....	.....	65.	1906	S. Sanford (F)
.....	0.	.....	.....	.....	.....	.....	12. 410.	12. 410.	>30.	.....	.....	.....	.....	5.8	7.3	1906	S. Sanford (F)
.....	.....	.....	.....	.....	.....	.....	.....	.....	35.	0.	.....	.....	.....	2.	25.	.....	S. Sanford (F)
.....	little	.....	.....	.....	.....	.....	tr. 230.	tr. 230.	>30.	.....	.....	.....	.....	3.	19.	1906	S. Sanford (F)
.....	little	.....	.....	.....	.....	.....	22. 402.	22. 402.	10.	.....	.....	.....	.....	106.	.....	1906	R. B. Dole (F)
.....	tr.	.....	.....	.....	.....	.....	12. 680.	12. 680.	tr.	.....	.....	.....	.....	25.	3.2	1906	S. Sanford (F)
.....	tr.	.....	.....	.....	.....	.....	12. 670.	12. 670.	tr.	.....	.....	.....	.....	30.	8.	1906	S. Sanford (F)
.....	much	.....	.....	.....	.....	.....	0. 75.	0. 75.	>30.	.....	.....	.....	.....	147.	100.	1906	S. Sanford (F)
.....	much	.....	.....	.....	.....	.....	0. 190.	0. 190.	little	.....	.....	.....	.....	4.2	110.	1906	S. Sanford (F)
.53	.008	2.6	1.1	169.	6.2	.008	204.	.....	11.	.85	.....	.36	.0004	25.	.....	1903	Froehling & Robertson
.64	tr.	3.9	1.4	193.	11.	tr. ^c	.....	518.	1.6	.17	.75	.73	.77	17.	.....	1907	Froehling & Robertson
1.2	tr.	7.	2.6	188.	6.1	.....	175.	133.	9.	.13 ^d	tr.	.012	.012	27.	.....	1907	Froehling & Robertson
.....	little	.....	.....	.....	.....	.....	30.	370.	tr.	.....	.....	.....	.....	5.	14.	1907	S. Sanford (F)
.....	2.76	4.1	140.	.....	.....	.....	185.	.....	12.5	.....	.....	.....	.....	4.	.....	1909	N. S. Hill
.....	2.9	tr.	130.	11.	tr.	.....	350.	350.	5.8	.2	.....	.....	.....	2.7	10.	.....	.....
.....	.....	.....	.....	.....	.....	.....	6.1	310.	.....	.....	.....	.....	.....	135.	3.8	1906	S. Sanford (F)
.....	7.2	2.7	185.	16.	.....	.....	14. 280.	14. 280.	tr.	.....	.....	.....	.....	57.	3.8	1906	S. Sanford (F)
.....	12.	3.7	131.	.....	.....	.....	179.	179.	10.	.....	.....	.....	.....	103.	.....	.....	W. H. Taylor
.....	53.	2.2	107.	.....	.....	.....	198.	198.	21.	.....	.....	.....	.....	149.	.....	.....	Keystone Chemical Co.
.....	much	.....	.....	.....	.....	.....	.....	360.	mod.	.....	.....	.....	.....	14.	.....	.....	Henry Froehling
.....	8.	4.3	191.	17.	.....	.....	188.	188.	10.	.....	.....	.....	.....	15.	480.	.....	S. Sanford (F)
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	107.	.....	.....	W. H. Taylor
.....	mod.	.....	.....	.....	.....	.....	0. 36.	0. 36.	>30.	.....	.....	.....	.....	170.	58.	1906	S. Sanford (F)
.....	0.	.....	.....	.....	.....	.....	0. 260.	0. 260.	>30.	.....	.....	.....	.....	3.	21.	1906	S. Sanford (F)
.86	4.8	47.	213.	14.	e	.....	306.	306.	307.	.6	tr.	.18	.04	6.7	.....	.....	Henry Froehling
.....	tr.	.....	.....	.....	.....	.....	230.	230.	tr.	.....	.....	.....	.....	6.	14.	1906	(F.)
.....	little	.....	.....	.....	.....	.....	0. 480.	0. 480.	>30.	.....	.....	.....	.....	18.	10.	1906	S. Sanford (F)

TABLE 8 (Continued)—Analyses and field assays (F) of well water from Chesapeake formations.

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO ₂)	Iron and aluminum oxides (Fe ₂ O ₃ +Al ₂ O ₃)	Iron (Fe)
MIDDLESEX								
Urbanna	G. V. Wagenen	drilled	232.					
Dew	D. M. Nelson	drilled	297.					
NANSEMOND								
Everetts	T. J. Saunders	drilled	54.					tr.
NORFOLK								
Norfolk	Pocomoke Guano Co.	drilled	86.	600.				
NORTHAMPTON								
Bone Island		drilled	169.					1.5
Oyster	W. F. Travis	drilled	185.				tr.	
Sandy Island	Wharton Fisheries Co.	drilled	249.					tr.
Sandy Island	Wharton Fisheries Co.	drilled	249.	918.				little
NORTHUMBERLAND								
Coans	Thomas Fallin	drilled	260.					1.5
Hardings	Wharton Fisheries Co.	drilled		402.				.13
Lodge	Wharton Fisheries Co.	drilled	255.	220.				tr.
RICHMOND								
Warsaw	E. H. Garland	drilled	188.					1.
Warsaw	G. M. Sydnor	drilled	180.					
SOUTHAMPTON								
Boykins	Baptist Church	drilled	127.					tr.
Boykins	E. H. Grizzard	drilled	85.					tr.
Boykins	W. A. Powell	drilled	110.					tr.
Boykins	Town	drilled	90.					tr.
Courtland	R. T. Whitfield.	drilled	165.	277.	20.	25.		.9
	Railroad	drilled		244.	23.	27.		.16
SURRY								
Homewood	W. F. Gray	drilled	250.					tr.
Homewood	W. F. Gray	drilled	315.	785.		37.		.1
WESTMORELAND								
Beales Wharf	Beales & Biddle.	drilled	175.					
Kinsale	G. P. Bailey	drilled	238.					tr.
Kinsale	Dameron & Courtney	drilled	275.					
Lynch's Point	J. R. Dos Passos	drilled	90.					5.
Mount Holly	S. J. Hopkins	drilled	135.					
Sandy Point	J. R. DosPassos	drilled	250.					
WARWICK								
Curtis Point	Philip Lederhos	drilled	363.	910.		18.		.12
Mulberry Island	P. H. Wright	drilled	373.	1,158.		13.		tr.
Mulberry Island	P. H. Wright	drilled	373.					tr.

^aAmmonium radicle (NH₄) 9.7; borate radicle (B₂O₇) trace.^bSodium and potassium.

TABLE 8 (Continued)—Analyses and field assays (F) of well water from Chesapeake formations.

Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO ₃)	Bicarbonate radicle (HCO ₃)	Sulphate radicle (SO ₄)	Phosphate radicle (PO ₄)	Nitrate radicle (NO ₃)	Bromine (Br)	Iodine (I)	Chlorine (Cl)	Total hardness as CaCO ₃	Date	Analyst
.....	little	.....	.....	.....	.....	.....	16.	450.	tr.	.....	.....	.....	.....	9.5	5.6	1906	S. Sanford (F)
.....	little	.....	.....	.....	.....	.....	15.	360.	>30.	.....	.....	.....	.....	12.	8.	1906	S. Sanford (F)
.....	.....	.....	.....	.....	.....	.....	.....	220.	tr.	.....	.....	.....	.....	6.	81.	1906	S. Sanford (F)
.....	74.	31.	50.	.....	.....	.....	292.	.....	.....	.....	.....	.....	.....	78.	.....	1905	Sparrows Point Boiler Compound Co.
.....	much	.....	.....	.....	.....	.....	0.	240.	>30.	.....	.....	.....	.....	610.	140.	1907	S. Sanford (F)
.....	mod.	.....	.....	.....	.....	.....	5.	200.	0.	.....	.....	.....	.....	19.	70.	1906	S. Sanford (F)
.....	some	.....	.....	.....	.....	.....	0.	210.	>30.	.....	.....	.....	.....	420.	95.	1906	S. Sanford (F)
.....	some	some	.....	.....	.....	some	.....	.....	little	.....	.....	.....	.....	427.	.....	1901	C. B. Dudley
.....	some	.....	.....	.....	.....	.....	0.	260.	0.	.....	.....	.....	.....	6.7	40.	1906	S. Sanford (F)
.....	7.2	1.8	.....	.....	.....	.....	24.	396.	.3	.....	.....	.....	.....	6.6	.....	1907	R. B. Dole
.....	.....	.....	.....	.....	.....	.....	.....	.....	0.	.....	0.	.....	.....	4.	42.	.....	G. W. Lehmann
.....	mod.	.....	.....	.....	.....	.....	0.	250.	>30.	.....	.....	.....	.....	5.	32.	1906	S. Sanford (F)
.....	little	.....	.....	.....	.....	.....	0.	210.	0.	.....	.....	.....	.....	4.	34.	1906	S. Sanford (F)
.....	some	.....	.....	.....	.....	.....	0.	170.	>30.	.....	.....	.....	.....	6.	62.	1907	S. Sanford (F)
.....	little	.....	.....	.....	.....	.....	0.	170.	>30.	.....	.....	.....	.....	5.2	42.	1907	S. Sanford (F)
.....	little	.....	.....	.....	.....	.....	.....	150.	tr.	.....	.....	.....	.....	7.	21.(?)	1907	S. Sanford (F)
.....	little	.....	.....	.....	.....	.....	.....	150.	tr.	.....	.....	.....	.....	5.3	50.	1907	S. Sanford (F)
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.	.....	.....	.....	19.	16.	1909	N. S. Hill
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.	.....	.....	.....	18.	25.	1909	N. S. Hill
.....	0.	.....	.....	.....	.....	.....	15.	425.	>30.	.....	.....	.....	.....	35.	7.3	1906	S. Sanford (F)
.....	6.8	2.2	295 ^b	.....	.....	.....	23.	468.	26.	.....	.3	.....	.....	152.	.....	.....	R. B. Dole
.....	little	.....	.....	.....	.....	.....	0.	185.	>30.	.....	.....	.....	.....	6.	12.	1906	S. Sanford (F)
.....	little	.....	.....	.....	.....	.....	0.	210.	>30.	.....	.....	.....	.....	5.3	23.	1900	S. Sanford (F)
.....	little	.....	.....	.....	.....	.....	0.	220.	>30.	.....	.....	.....	.....	5.3	.....	1906	S. Sanford (F)
.....	some	.....	.....	.....	.....	.....	0.	320.	much	.....	.....	.....	.....	7.	50.	1900	S. Sanford (F)
.....	some	.....	.....	.....	.....	.....	0.	180.	>23.	.....	.....	.....	.....	5.	18.	1906	S. Sanford (F)
.....	little	.....	.....	.....	.....	.....	.....	250.	>30.	.....	.....	.....	.....	5.7	13.	1906	S. Sanford (F)
.....	7.2	1.2	350 ^b	.....	.....	.....	22.	448.	32.	.....	tr.	.....	.....	244.	.....	1902	R. B. Dole
.....	4.2	1.2	354.	15.	tr.	.....	.....	454.	44.	.....	.....	.....	.....	273.	.....	1905	W. H. Taylor
.....	.....	.....	.....	.....	.....	.....	6.	400.	39.	.....	.....	.....	.....	250.	11.	1906	S. Sanford (F)

TABLE 9—*Analyses and field assays of well water from Pamunkey formations.*

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO ₂)	Iron and aluminum oxides (Fe ₂ O ₃ +Al ₂ O ₃)	Iron (Fe)
CAROLINE								
Port Royal	Town	drilled	235					
CHARLES CITY								
Roxbury	Thos. Walker	drilled	250					tr.
Westover	W. S. Ramsay	drilled	135					tr.
ESSEX								
Tappahannock	F. S. McDaniel	drilled	280					tr.
Tappahannock	R. T. Cauthorn	drilled		494.	48.			
Tappahannock	Donaldson & Schultiz	drilled	256					
GLOUCESTER								
Sassafras	B. F. Weaver	drilled	336					2.
Achilles	Union Church	drilled	500					5.5
JAMES CITY								
Lee Hall	Duke & Smith	drilled	429					tr.
Lee Hall	Duke & Smith	drilled	395					tr.
Norge	Chesapeake & Ohio Ry.	drilled	419	718.	9.9	40.	6.	
KING GEORGE								
Mathias Point	C. H. Pemberton	drilled	286					tr.
Port Conway	R. V. Turner	drilled	232					tr.
Port Conway	J. H. Low	drilled	305					tr.
Port Conway	R. V. Turner	drilled	250					
Port Conway	Dr. Jones	drilled	305					.3
Wilmington Landing	Vulcan Fire Brick Co.	drilled	300(?)					
KING WILLIAM								
Aylett	J. B. Moore	drilled	190	303.		17.		.2
Eising Green	Roger Gregory	drilled	300					tr.
West Point	West Point Waterworks	drilled	335					tr.
KING AND QUEEN								
King and Queen	County	drilled	216					1.
Walkerton	Ivan Clark	drilled	235					tr.
LANCASTER								
Irvington	Carters Creek Fish Guano Co.	drilled	580					tr.
NEW KENT								
Boulevard	Wm. Webber	drilled	260	60.		23.		.08
Providence Forge	E. B. Richardson	drilled	215					tr.
Providence Forge	E. B. Townsend	drilled	250					tr.
NORTHUMBERLAND								
Harding	S. A. Whitaker	drilled		462.			.13	
RICHMOND								
Naylors Wharf	E. A. Waddington	drilled	320					
WESTMORELAND								
Colonial Beach	M. A. & E. S. Bentley	drilled	200					tr.
Colonial Beach	L. W. Jett		230					
Colonial Beach	Ice Works	drilled	235					
Erica	E. T. Barrett	drilled	335					tr.
Erica	Wm. Detrick	drilled	327					tr.
Wilkerson	W. S. Wilkerson	drilled	233					tr.
STAFFORD								
Brooke	Richmond, Fredericksburg and Potomac R. R. Co.	dug	20					tr.

TABLE 9 (Continued)—Analyses and field assays of well water from Pamunkey formations.

Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Strontium (Sr)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO ₃)	Bicarbonate radicle (HCO ₃)	Sulphate radicle (SO ₄)	Nitrate radicle (NO ₃)	Chlorine (Cl)	Total hardness as CaCO ₃	Date	Analyst
.....		little	.....	.....	.....	.....	.....	0.	180.	>30.	.....	6.	5.	1906	S. Sanford (F)
.....		0.(?)	.....	.....	.....	.....	.....	0.	195.	>30.	.....	2.5	14.	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	0.	405.	>30.	.....	54.?	31.	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	8.4	470.	>30.	.....	7.5	11.	1906	S. Sanford (F)
.....								0.	210.	>30.	.....	2.	25.	1904	G. H. Lehmann
.....												8.6	56.	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	>10.	645.	54.	.....	220.	18.	1906	S. Sanford (F)
.....		mod.	.....	.....	.....	.....	.....	0.	800.	135.	.....	1,500.	67.	1906	S. Sanford (F)
.....		0.(?)	.....	.....	.....	.....	.....	0.	440.	>30.	.....	190.	7.3	1906	S. Sanford (F)
.....		0.(?)	.....	.....	.....	.....	.....	0.	470.	>30.	.....	280.	12.	1906	S. Sanford (F)
.....		11.	.....	3.1	252.	.....	.....	180.	.....	39.	.....	176.	.....	1910	Froehling & Robertson
.....		0.(?)	.....	.....	.....	.....	.....	0.	250.	>30.	.....	12.5	7.	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	0.	140.	>30.	.....	5.	1.	1906	S. Sanford (F)
.....								0.	190.	>30.	.....	.....	.....	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	0.	240.	>30.	.....	>10.	.....	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	0.	190.	>30.	.....	5.	2.	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	0.	270.	>30.	.....	5.	.....	1906	S. Sanford (F)
.....		3.2	.....	.4	105.	8.8	.....	22.	245.	18.	0.	1.0	.....	1906	R. B. Dole
.....		little	.....	.....	.....	.....	.....	0.	360.	>30.	.....	>10.	14.	1906	S. Sanford (F)
.....		0.(?)	.....	.....	.....	.....	.....	0.	480.	>30.	.....	17.5	2.	1906	S. Sanford (F)
.....								0.	220.	>30.	.....	7.5	41.	1906	S. Sanford (F)
.....		0.(?)	.....	.....	.....	.....	.....	13.	280.	>30.	.....	3.	7.3	1906	S. Sanford (F)
.....		0.(?)	.....	.....	.....	.....	.....	20.	500.	>30.	.....	13.	1.	1906	S. Sanford (F)
.6		2.1	.....	.4	9.2	.....	.....	0.	29.	1.6	4.4	6.5	.....	1906	R. B. Dole
.....		little	.....	.....	.....	.....	.....	0.	200.	>30.	.....	4.	24.	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	10.?	300.	>30.	.....	3.8	10.	1906	S. Sanford (F)
.....		7.2	.....	1.8	.....	.....	.....	24.	396.	.3	.....	5.5	.....	1907	R. B. Dole
.....		tr.	.....	.....	.....	.....	.....	15.	390.	.....	.....	7.6	.....	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	8.	330.	>30.	.....	11.	12.	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	15.	270.	>30.	.....	10.	16.	1906	S. Sanford (F)
.....		5.	.....	3.6	127.	.....	.....	0.	354.	20.	.....	>10.	.....	1906	M. G. Roberts
.....		little	.....	.....	.....	.....	.....	0.	340.	>30.	.....	13.	13.	1906	S. Sanford (F)
.....								20.	395.	>30.	.....	5.	11.	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	18.	380.	>30.	.....	9.	11.	1906	S. Sanford (F)
.....		little	.....	.....	.....	.....	.....	0.	25.	>30.	.....	9.	5.6	1906	S. Sanford (F)

TABLE 10—*Analyses and field assays (F) of well water from Upper Cretaceous formations.*

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO ₂)
ELIZABETH CITY						
Fort Monroe	Hotel Chamberlain.....	drilled	945.	9,131.	47.	20.
Fort Monroe	Hotel Chamberlain.....	drilled	945.	9,248.	.....	14.
Fort Monroe	Hotel Chamberlain.....	drilled	945.	8,846.	.....	.....
Fort Monroe	Hotel Chamberlain.....	drilled	945.	.....	.....	.....
GLOUCESTER						
Achilles	B. A. Rowe	drilled	600.	.....	.....	.....
Gloucester Point	County and Chesapeake Steamship Co.	drilled	694.	.....	.....	.....
Roanes	A. W. Withers	drilled	716½	3,417.	.....	20.
Seyern	J. M. Shakelford	drilled	610.	5,008.	.....	39.
KING WILLIAM						
Manquin	E. B. Chapman.....	drilled	237.	232.	.....	33.
Manquin	Miss Cora Skidmore.....	drilled	270.	.....	.....	tr.
LANCASTER						
Ocran .....	.....	drilled	660.	616.	.....	56.
MIDDLESEX						
Urbanna	J. W. Hurley	drilled	650.	.....	.....	.....
NANSEMOND						
Suffolk	Norfolk & Portsmouth Traction Co...	drilled	303.(?)	596.	20.	.....
NORFOLK						
Lamberts Point	N. & W. R. R.	drilled	616.	1,093.	.....	10.
Lamberts Point	N. & W. R. R.	drilled	616.	.....	.....	16.
Lamberts Point	N. & W. R. R.	drilled	616.	.....	.....	11.
Lamberts Point	N. & W. R. R.	drilled	616.	.....	.....	.....
Lamberts Point	N. & W. R. R.	drilled	616.	1,067.	.....	8.56
Lamberts Point	N. & W. R. R.	drilled	616.	86.	.....	2.4
Lamberts Point	N. & W. R. R.	drilled	616.	1,128.	.....	6.
NORTHUMBERLAND						
Fairport .....	.....	.....	690?	214.	80.	.....

*Sodium and potassium.

TABLE 10—(Continued)—Analyses and field assays (F) of well water from Upper Cretaceous formations.

Iron and aluminum oxides (Fe ₂ O ₃ +Al ₂ O ₃)	Iron (Fe)	Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO ₃)	Bicarbonate radicle (HCO ₃)	Sulphate radicle (SO ₄)	Nitrate radicle (NO ₃)	Chlorine (Cl)	Total hardness as CaCO ₃	Date	Analyst
16.	16.	23.	88.	71.	3,339.	87.	tr.	328.	433.	251.	tr.	4,929.	133.	1906	Penniman & Brown	
			97.	44.	3,268.				265.	4978.		4,978.		1906	W. H. Taylor	
	6.		mod.					5.	740.	180.		4,530.	70.	1896	Booth, Garrett & Blair	
														1906	S. Sanford (F)	
	2.5		much					5.(?)	840.	160.		1,400.	57.	1906	S. Sanford (F)	
	1.		little					6.	730.	38.		410.	21.	1906	S. Sanford (F)	
	1.		23.	14.	1,188. ^a			21.	544.	155.	tr.	1,630.		1906	R. B. Dole	
	4.9		46.	26.	1,826. ^a			0.	628.	216.	.7	2,500.		1906	R. B. Dole	
	1.		1.4	.2	74.	5.		6.7	188.	13.	0.	1.1		1906	R. B. Dole	
	tr.		little					0.	210.	>30.		>10.	2.	1906	S. Sanford (F)	
	tr.		little	little	much	s'm e...		much	...	some		some		1907	G. H. Seyms	
	tr.		0.					14.	315.	>30.		9.	0.	1906	S. Sanford (F)	
	tr.		2.9	1.7	<214.			<280.	...	9.8	0.	23.	13.	1904	First Scientific Station for the Art of Brewing	
0.91			5.	1.7	415.	21.		245.	...	43.		351.		1891	Shepard Laboratory	
2.3			5.2	2.4	459.				601.	43.		291.		1906	N. & W. Railway	
2.6			4.8	2.7	434.				617.	43.		293.		1907	Dearborn Laboratories	
	.5		little					9.	560.	41.		290.		1906	S. Sanford (F)	
	1.37		3.9	2.2	340.	11.		370.	...	45.		300.			N. & W. Railway	
1.2			6.3	4.7	16.5			10.	...	20.		23.		1909	N. & W. Railway	
1.9			5.1	3.3	437.			312.	...	45.		290.		1909	N. & W. Railway	
										0.	0.	6.	67.		G. H. Lehmann	

TABLE 11—*Analyses and field assays (F) of well water from Potomac formations.*

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO ₂)
ALEXANDRIA Alexandria	New Washington Brick Co.			86.		33.
Alexandria	Belle Pre Bottle Co.	drilled	155.	110.		38.
Alexandria	Mutual Ice Co.	drilled	401.	176.		21.
Alexandria	Robert Portner Brewing Co.	drilled	431.	170.	14.	
Alexandria	Robert Portner Brewing Co.	drilled	400?	205.		27.
Alexandria	Robert Portner Brewing Co.	drilled	431.			
FAIRFAX Fort Hunt	United States	drilled	215.	342.		
GLOUCESTER Roanes	Joseph Bryan		850.(?)			
KING GEORGE Sealston	John Curtis	drilled	250.			
KING WILLIAM Palls	J. H. Montague	drilled	399.			
MATHEWS Mathews C. H.	County	drilled	817.			
PRINCE GEORGE City Point	Misses Eppes	drilled	111.	179.		23.
PRINCESS ANNE Waterway	Norfolk City Waterworks	drilled	1,100.(?)			
SOUTHAMPTON Sebrell	Tidewater Railway	drilled	344.	295.	9.9	78.
SPOTTSYLVANIA Fredericksburg	E. D. Cole	drilled	120.	43.	4.3	12.

^aSodium and potassium.^bOxide and carbonate of iron 6.8

TABLE 11 (Continued)—Analyses and field assays (F) of well water from Potomac formations.

Iron and aluminum oxides (Fe ₂ O ₃ +Al ₂ O ₃)	Iron (Fe)	Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO ₃)	Bicarbonate radicle (HCO ₃)	Sulphate radicle (SO ₄)	Nitrate radicle (NO ₃)	Chlorine (Cl)	Total hardness as CaCO ₃	Date	Analyst
.....	1.4	.....	4.1	2.6	10.	.....	.....	.....	0.	30.	11.	0.	6.9	.....	1910	Chase Palmer
.....	4.6	.....	6.5	3.9	12.	.....	.....	.....	0.	51.	6.4	1.	13.	.....	1910	Chase Palmer
.....	.....	.....	tr.	1.4	49.	.....	.....	.....	.....	39.	36.	.....	32.	.....	1899	J. D. Hird
4.	.....	.....	7.1	.0	.....	.....	.....	.....	.....	.....	17.	0.	19.5	200.	1903	First Scientific Station for the Art of Brewing
.....	1.	.....	8.6	19.	32.	.....	.....	.....	tr.	105.	3.	tr.	47.	.....	1910	Chase Palmer
.....	tr.	.....	.....	.....	.....	.....	.....	.....	.....	130.	>30.	.....	44.	.....	.....	S. Sanford (F)
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.4	.....	.....	W. Mew
.....	2.5	.....	mod.	.....	.....	.....	.....	.....	11.	660.	100.	.....	1,090.	33.	1906	S. Sanford (F)
.....	.....	.....	mod.	.....	.....	.....	.....	.....	0.	120.	tr.	.....	.....	.....	1906	S. Sanford (F)
.....	tr.	.....	tr.	.....	.....	.....	.....	.....	0.	175.	>30.	.....	5.	7.5	.....	S. Sanford (F)
.....	3.	.....	much	.....	.....	.....	.....	.....	0.	678.	tr.	.....	167.	.....	1906	R. B. Dole (F)
.....	.4	.....	52.	3.2	16. ^a	.....	.....	.....	0.	155.	5.3	6.	16.	.....	1906	R. B. Dole (F)
.....	tr.		little						5.	610.	110.		1,080.	7.5	1906	S. Sanford (F)
2.1			.79	.26	82.				84.		25.		10.6		1901	
(b)			.5	2.9	3.3				10.		3.5					J. N. Barney

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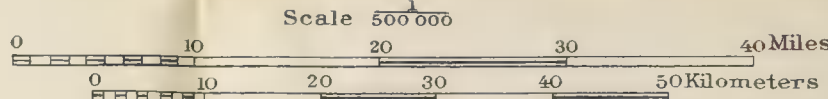
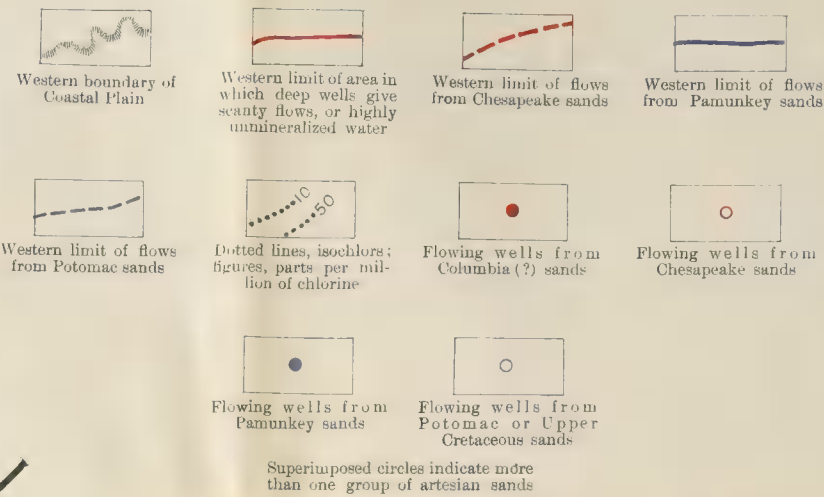
VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA
THOMAS LEONARD WATSON, Director

MAP OF THE COASTAL PLAIN OF VIRGINIA

Showing flowing wells and limits of flow, at an elevation of twenty feet, from different artesian sands, and probable variation in chlorine content of artesian water 200 to 700 feet below sea level in southeastern part of the Virginia Coastal Plain.

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SAMUEL SANFORD
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VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

THOMAS LEONARD WATSON, PH. D.

DIRECTOR

Bulletin No. VI

Biennial Report

ON THE

Mineral Production of Virginia

During the Calendar Years

1909 and 1910

BY

THOMAS LEONARD WATSON

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Director of the Survey, and Professor of Geology in the University of Virginia

CHARLOTTESVILLE
UNIVERSITY OF VIRGINIA
1911

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THOMAS LEONARD WATSON,
Director of the Survey.

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LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, October 20, 1911.

*To His Excellency, Hon. Wm. Hodges Mann, Governor of Virginia, and
Chairman of the State Geological Commission:*

SIR:—I have the honor to transmit herewith for publication, as Bulletin No. VI of the Virginia Geological Survey Series of Reports, a Biennial Report on the Mineral Production of Virginia during the Calendar Years 1909 and 1910, prepared by the Director of the Survey. In this report is given full information descriptive of the mining industry in Virginia during the calendar years 1909 and 1910.

Respectfully submitted,

THOMAS L. WATSON,

Director.

INTRODUCTION

Virginia is possessed of an abundance and variety of mineral materials. Many of these have been worked since early colonial days, especially the coal, iron ores, and brick clays. About 40 materials are now exploited, many of them on a large scale, which afford a basis of important commercial enterprises, and give to the State prominence in a varied and extensive mining industry. Most of the materials now produced can be developed still further with an increased production in future years. Some of these have been developed within recent years, and others still have not yet been exploited.

This bulletin gives full information descriptive of the mining industry in Virginia during the calendar years 1909 and 1910, including a brief treatment of the distribution, occurrence, development, and production of the mineral materials of the State. It has been prepared with the hope that it will be of service to those now engaged in exploitation of our resources, or otherwise interested in them. The statistics of mineral production in Virginia for the calendar year 1909 were collected by the Federal Survey in coöperation with the Bureau of the Census and furnished by courtesy of the Federal Survey to the Virginia Geological Survey. The statistics for the calendar year 1910 were collected by the Virginia Geological Survey in coöperation with the United States Geological Survey. The total number of productive operations is large, including a variety of subjects, as is indicated in the tables of annual production below. The aggregate value of their output in 1910, according to returns received at the State Survey office, amounted to \$22,755,161.

The statistics of production and value of the mineral resources of Virginia for 1909 and 1910 are given below in tabular form. The figures are well above the totals of most of the materials recorded in previous years. The increase in 1909 and 1910 over that of 1908 is especially noticeable in the large industries and in many of the smaller ones.

There are given in the tables below the production and value of the various mineral materials in Virginia for the years 1906 to 1910, inclusive.

Mineral Production of Virginia in 1906.

Product	Unit of Measurement	Quantity	Value
Barytes	Short tons	11,775	\$ 45,336
Clay	Short tons	2,903	24,354
Clay products .....	.....	.....	1,966,078
Coal	Short tons	4,254,879	4,183,991
Coke	Short tons	1,577,659	3,611,659
Ammonium sulphate ..	Pounds .....	.....	} a685,738
Coal tar	Gallons .....	.....	
Gas, illuminating	Cubic feet .....	.....	
Gas coke	Short tons .....	.....	
Gold (mines report).....	Fine ounces (Troy)....	717.50	14,832
Iron ores	Long tons	828,081	1,579,817
Iron, pig	Long tons	483,525	a8,591,000
Lime	Short tons	104,486	382,083
Manganese ores	Long tons	6,028	77,522
Millstones .....	.....	.....	15,611
Mineral waters	Gallons	1,997,207	418,908
Precious stones .....	.....	.....	500
Pyrite	Long tons	128,794	431,388
Sand and gravel.....	Short tons	335,178	121,951
Silver (mines report).....	Fine ounces (Troy)....	250	168
Slate .....	.....	.....	172,857
Stone .....	.....	.....	606,343
Talc and soapstone.....	Short tons	23,624	590,800
Zinc	Short tons	1,143	139,446
Other products .....	.....	.....	b990,432
Total value.....	.....	.....	\$24,650,814

aEstimated.

bIncludes asbestos, natural cement, Portland cement, gypsum, mica, ocher, pottery, quartz (flint), salt, sand-lime brick, and titanium.

Mineral Production of Virginia in 1907.

Product	Unit of Measurement	Quantity	Value
Barytes	Short tons	9,254	\$ 32,833
Clay products .....	.....	.....	1,611,335
Coal	Short tons	4,710,895	4,807,533
Coke	Short tons	1,545,280	3,765,733
Ammonium sulphate ..	Pounds .....	.....	} 1,165,821
Coal tar	Gallons .....	.....	
Gas, illuminating	Cubic feet .....	.....	
Gas, water	Cubic feet .....	.....	
Gas coke	Short tons .....	.....	} 11,402
Copper	Pounds	57,008	
Glass sand	Short tons	1,246	4,535
Gold	Fine ounces (Troy)....	402	8,300
Iron ores	Long tons	786,856	1,538,920
Iron, pig	Long tons	478,771	8,963,000
Lead	Short tons	82	8,692
Lime	Short tons	115,155	447,307
Manganese ores	Long tons	4,604	56,469
Mica .....	.....	.....	1,014
Millstones .....	.....	.....	4,684
Mineral waters	Gallons	2,442,075	431,770
Precious stones .....	.....	.....	520
Pyrite	Long tons	124,740	372,586
Sand and gravel.....	Short tons	266,976	119,277
Silver	Fine ounces (Troy)....	200	100
Slate .....	.....	.....	173,670
Stone .....	.....	.....	760,488
Tale and soapstone.....	Short tons	26,278	631,880
Zinc	Short tons	771	90,978
Other products .....	.....	.....	a774,809
Total value.....	.....	.....	\$25,783,656

aIncludes natural and Portland cement, feldspar, gypsum, ocher, rutile, and sand-lime brick.

Mineral Production of Virginia in 1908.

Product	Unit of Measurement	Quantity	Value
Clay	Short tons	442	\$ 3,250
Clay products			1,536,907
Coal	Short tons	4,259,042	3,868,524
Coke	Short tons	1,162,051	2,121,980
Ammonium sulphate ..	Pounds		} 1,180,744
Coal tar	Gallons		
Gas, illuminating	Cubic feet		
Gas, water	Cubic feet		
Gas coke	Short tons		}
Copper	Pounds	24,775	
Gold (mines report).....	Fine ounces (Troy)....	118.57	3,270
Granite			2,451
Iron ores	Long tons	692,223	321,530
Iron, pig	Long tons	320,458	1,465,691
Lead	Short tons	38	4,578,000
Lime and cement.....	Barrels	1,629,178	3,200
Limestone			775,660
Manganese ores	Long tons	6,418	280,542
Mica	Pounds (sheet)	13,427	} 63,324
	Tons (scrap)	46	
Millstones and sandstone..			7,346
Mineral waters	Gallons		10,554
Pyrite	Long tons	a2,009,614	207,115
Sand and gravel.....		116,340	435,522
Sand-lime brick.....	Thousands	6,181	119,095
Silver	Fine ounces (Troy)....	236	36,934
Slate	Squares	41,678	125
Talc and soapstone.....	Short tons	19,616	194,356
Zinc	Short tons	705	458,252
Other products			66,315
Total value.....			b143,135
			\$17,883,822

aExclusive of 119,672 gallons used for soft drinks.

bIncludes barytes, feldspar, gypsum, mineral paint, and salt.

Mineral Production of Virginia in 1909.

Product	Unit of Measurement	Quantity	Value
Clay products			\$ 1,957,367
Coal	Short tons	4,752,217	4,251,056
Coke	Short tons	1,347,478	2,415,769
Copper	Pounds	224,162	29,141
Gems and precious stones..			2,500
Gold (mines report).....	Fine ounces (Troy)....	181.41	3,750
Granite			488,250
Iron ores	Long tons	837,847	1,693,188
Iron, pig	Long tons	391,134	5,550,000
Lime	Short tons	166,695	635,946
Limestone			342,656
Mica			4,600
Millstones and sandstone..			40,922
Mineral waters	Gallons	1,504,530	203,455
Pyrite	Long tons	114,176	423,283
Sand and gravel	Short tons	847,476	281,177
Silver	Fine ounces (Troy)....	4,825	2,509
Slate	Squares	40,880	180,775
Talc and soapstone	Short tons	26,511	523,942
Zinc	Short tons	58	6,298
Other products ^a			799,086
Total			\$19,835,670

^aIncludes barytes, Portland cement, feldspar, gypsum, manganese ore, manganiferous ore, ocher, rutile, salt, and sand-lime brick.

Mineral Production of Virginia in 1910.

Product	Unit of Measurement	Quantity	Value
Clay products			\$ 1,841,731
Coal	Short tons	6,507,997	5,877,486
Coke	Short tons	1,493,665	2,731,348
Copper	Pounds	5,402	686
Gold (mines report).....	Fine ounces (Troy)....	42.96	888
Granite			503,106
Iron ores	Long tons	903,377	1,845,144
Iron, pig	Long tons	444,976	6,150,000
Lead	Pounds	198,850	8,750
Lime	Short tons	141,257	563,567
Limestone			471,903
Manganese ores	Long tons	1,758	17,892
Millstones			5,273
Mineral waters ^a	Gallons	2,441,923	301,523
Pyrite	Long tons	140,106	525,437
Sand and gravel	Short tons	764,321	215,416
Silver	Fine ounces (Troy)....	128	69
Slate	Squares	31,787	148,721
Talc and soapstone	Short tons	25,908	510,781
Zinc (spelter)	Pounds	1,588,112	85,758
Other products ^b			948,032
Total			\$22,755,161

^aExclusive of 48,252 gallons used in the manufacture of soft drinks.

^bIncludes barytes, Portland cement, feldspar, gypsum, infusorial earth, manganiferous ore, ocher, rutile, sand-lime brick, and salt.

PRELIMINARY GENERALITIES

GEOGRAPHIC POSITION OF VIRGINIA.

The State of Virginia is situated on the Atlantic slope of the Appalachian Mountains, halfway between Maine and Florida. It is included between the parallels $36^{\circ} 31'$ and $39^{\circ} 27'$ north latitude, and between the meridians $75^{\circ} 13'$ and $83^{\circ} 37'$ west longitude, extending from the sea-coast westward beyond the Great Valley to the Alleghany Front. The extreme length of the State from the Atlantic border to Kentucky is 476 miles, and the greatest width from north to south is 192 miles; its area is 42,450 square miles. Of this area, 2,325 square miles are covered with water, giving 40,125 square miles of land surface. Its principal inland waters are the Chesapeake and Mobjack bays, Hampton Roads, and Lake Drummond. Except in the eastern section, no navigable streams traverse the State, and transportation is necessarily limited to railways.

SURFACE FEATURES OF THE STATE.^a

Considered with reference to its surface features Virginia is divided into three major provinces: (1) An eastern plain region usually designated the Coastal Plain or Tidewater region; (2) a central or plateau region designated the Piedmont Plateau; and (3) a western or mountain region, designated the Appalachian Mountains province. The boundaries of these provinces are indicated on map, figure 1, page 8.

The three major provinces of the State differ markedly in the nature and origin of surface features, and in the age and kinds of rocks. They are intimately related to the geologic structure, and hence have an important bearing upon the mineral resources of the State. These are considered very briefly in order below.

^aA fuller discussion of this subject is contained in Bull. No. I-A of the State Geological Survey, 1909.

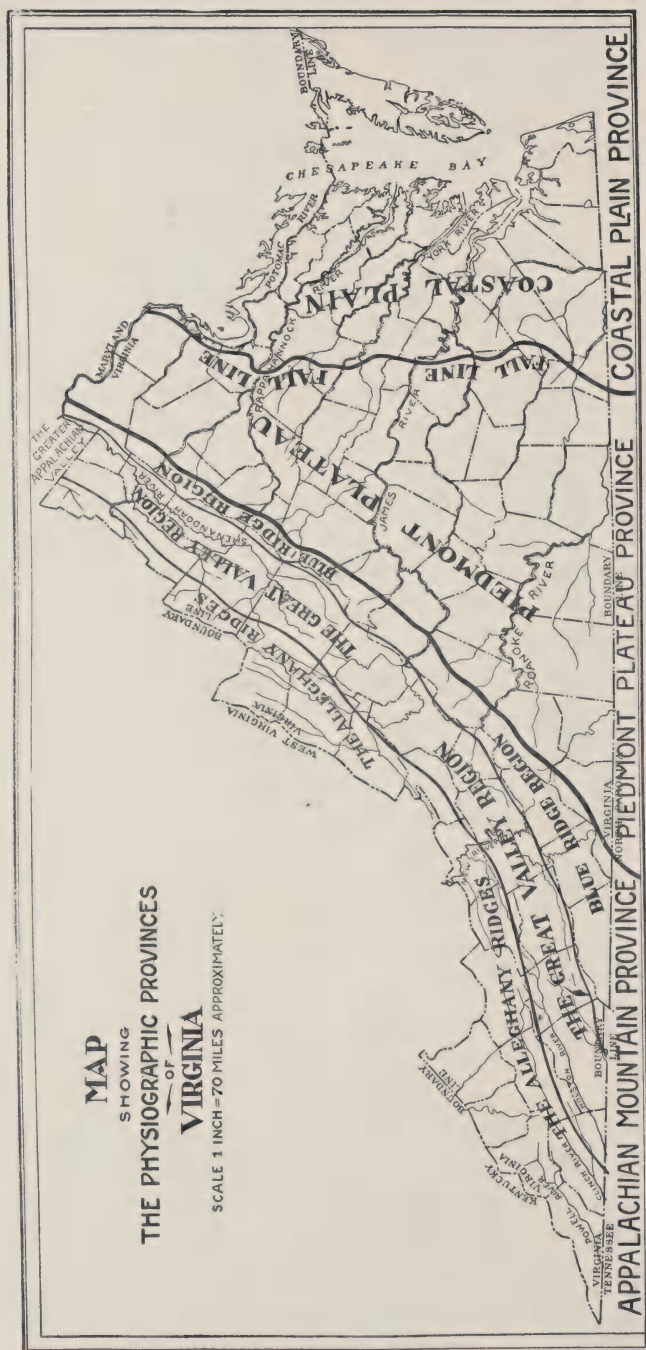


Fig. 1.—Sketch map of Virginia showing physiographic provinces.

The Coastal Plain Province.

The Virginia Coastal Plain province, the most easterly of the three larger physiographic provinces, and comprising approximately one-fourth of the total area of the State, is separated from the higher-lying Piedmont Plateau province on the west and the deep Atlantic Ocean basin on the east. The boundary of the Coastal Plain to the eastward is marked by the steep slope of the continental shelf, which lies from 30 to 50 miles east of the present shore-line. The western limit of the Coastal Plain is defined by the belt of metamorphic crystalline rocks known as the Piedmont Plateau province. The Virginia Coastal Plain region is more than 100 miles wide, and includes approximately 9,500 square miles of territory, or about one-fourth the total area of the State.

Because of marked geologic differences in the two provinces, the larger streams, and many of the smaller ones, are characterized by falls or rapids where they cross the western margin of the Coastal Plain, and they always show a marked decrease in the velocity of their currents from this point eastward. For this reason, the name "fall-line" has been given to this boundary, the position of which is marked on the accompanying map, figure 1, page 8.

The Coastal Plain region, characterized by broad, level-topped stretches of country of low relief, gradually declines in slope from the Piedmont border to the shore-line. The deposits consist chiefly of unconsolidated beds of sand, gravel, clay and marl, which may be locally indurated by a cement either of iron oxide or carbonate of lime. These indurated ledges in the vicinity of Aquia Creek and, in places, southward along the western margin representing the oldest formation of the Coastal Plain series, have afforded sandstone suitable for building purposes. The beds strike in general from north to south, although some variation occurs, with a low but variable easterly dip. In age, the Coastal Plain beds range from Lower Cretaceous to Quaternary.

The Chesapeake Bay affords unparalleled transportation facilities, and its principal tributaries, the Potomac, Rappahannock, York, and James rivers, give access to vessels as far westward as the Piedmont border—the "fall-line."

The Piedmont Plateau Province.

The Piedmont Plateau province lies between the Coastal Plain and the Appalachian Mountains. It extends from the eastern slope of the Blue Ridge eastward to the western margin of the Coastal Plain, and it widens southward (map, figure 1, page 8). Its width increases from about 40 miles in the northern portion along the Potomac River to nearly 175 miles along the Virginia-Carolina boundary. The sediments of the Coastal Plain lie across the bevelled edges of the crystalline rocks of the Piedmont, presenting such marked stratigraphic and lithologic contrast that the geologic boundary between the two provinces is sharply defined. The transition on the west is less sudden and well marked.

The Piedmont province contains a greater variety of mineral resources than either of the other two provinces. In general, the surface of the Plateau has a gentle southeastward slope from an average altitude of 1,000 feet along the western margin to from 200 to 400 feet on the east, where the plateau rocks pass beneath the Coastal Plain sediments. The topography of the plateau is that of a more or less smooth, broadly rolling or undulating upland of moderate elevation, into which the streams have rather deeply sunk their channels.

The drainage of the region is to the southeast into the Atlantic waters, and the major streams which traverse the plateau are the Potomac, Rappahannock, James, and Roanoke rivers.

The rocks of the Piedmont region are the oldest in the State and, excepting the areas of Triassic rocks, they are all crystalline. They comprise both sedimentary and igneous masses usually greatly altered from metamorphism. The region is made up of a complex of schists, gneisses, and granites, with, in places, areas of slate, quartzite, and limestone. This complex is intersected by intrusions of basic eruptive rocks belonging to several different types. Over parts of the eastern and central portions of the region are areas of altered volcano-sedimentary rocks which extend southwestward into North Carolina.

The age of the rocks of the region, excepting the areas of Triassic rocks, ranges from probable Archean to early Paleozoic.

The Appalachian Mountains Province.

The Appalachian Mountains province embraces the western portion of the State. Its eastern boundary is the southeastern slope of the Blue Ridge and its western limits are artificially drawn in the western boundary of the State. This province, like the Piedmont Plateau and Coastal Plain, extends northeast and southwest far beyond the limits of Virginia.

The topography of the Appalachian province is varied and picturesque. Three subdivisions of the province are recognized which, named from east to west, are: (1) The Blue Ridge; (2) the Great Valley; and (3) the Alleghany Ridges. The limits of these subdivisions are indicated on the map, figure 1, page 8.

The Blue Ridge, which forms the eastern boundary of the Appalachian province, maintains an uneven and knobby crest entirely across the State, in a northeast-southwest direction, and has an average elevation of not less than 2,000 feet above tide-level. The Blue Ridge is composed largely of pre-Cambrian rocks, represented in part, at least, by various igneous types, but sandstones and shales of Cambrian age are exposed along the western slope. It is a natural dividing line between the Paleozoic sediments comprising sandstones, limestones, and shales on the west, and the pre-Paleozoic and other rocks on the east.

The two most westerly sub-provinces, the Valley and the Alleghany Ridges, bounded by the two principal ranges, the Blue Ridge and the Alleghany Front, on the southeast and northwest, respectively, are here treated together under the Greater Valley region. Considered broadly, the Greater Valley region is composed of narrow valleys and linear ridges arranged in more or less complex relations. It is composed throughout of Paleozoic sediments, which range in age from Cambrian to Carboniferous. The principal rock-types include limestone, shale, and sandstone.

The rocks composing the Greater Valley region have been folded and faulted and subsequently greatly eroded. As a result of the folding and subsequent erosion, the edges of the formation form linear ridges and valleys, developing the well-known Appalachian type of topography.

EFFECTS OF WEATHERING AND EROSION.

The surface rocks over all parts of Virginia show some effects from atmospheric action. Of the three major provinces of the State described above, the Coastal Plain, on account of its very recent geologic history, has suffered the least. The remaining two provinces, Piedmont Plateau and Appalachian Mountains, bear striking evidence over all their parts of profound decay and erosion, which have resulted in the removal of vast quantities of rock material. Just how much of their surface has been lowered, or what vertical thickness of material has been removed from these land areas and carried seaward, would probably be very difficult to say, but that it has been large can not be doubted. Because of its greater geologic age and the vast length of time it has been a land area, the Piedmont Plateau has probably suffered the removal of the greatest thickness of material.

Through this process of weathering a mantle of varying thickness of decayed rock material overlies the still fresh or sound rock, except where the erosive action has not been too excessive and the slopes too steep for its accumulation. This residual material is loose and porous or incoherent, consisting usually of clay, sand and gravel, and on the immediate surface forms soil. On depth it passes by imperceptible gradation into the hard and fresh unaltered rock. The thickness of residual material varies from a few inches to, in extreme cases, 100 feet. Over many parts of the State, exposures of the hard rock are rare, except along the stream courses where the mantle has been cut through by erosion.

This process of rock decay is of very great economic importance. Workable ore deposits have been formed by it from sparsely disseminated and non-workable mineral matter in the original rocks. This is best illustrated in the manganese deposits, in a part of the iron and zinc deposits, and in other ore deposits of the State.

DIVERSITY OF RESOURCES.

There is probably no state in the Union, of the same area as Virginia, that can show a greater diversity in geologic resources. This is confirmed by the actual exploitation thus far made, and it might be naturally inferred from the position which the State occupies with

reference to disturbed and undisturbed areas as described above. As indicated above and from an examination of the geologic map, the State stretches from the Atlantic coast westward nearly entirely across the Appalachian Mountain system. Within this area are found rocks ranging in age from pre-Cambrian to Recent, and representing all the principal divisions of geologic time. Equally as great a variety of rock-types, both sedimentary and igneous, of structure which characterizes both profoundly disturbed and undisturbed rock masses, and of topography, is shown.

The mineral products^a that have been mined and quarried in Virginia are discussed in this bulletin in the following order: Iron ores, manganese ores, gold and silver, copper, lead and zinc, tin, nickel and cobalt, coal and coke, clay and clay products, lime and cement, sand and gravel, sand-lime brick, stone (granite, marble, limestone, sandstone, slate, crushed stone, and furnace flux), abrasive materials (corundum, emery, and millstones), silica (quartz, chert, and diatomaceous earth), mica, feldspar, asbestos, talc and soapstone, barytes, gypsum, salt, mineral paints, marl, pyrite and pyrrhotite, arsenic, phosphate, graphite, rutile (titanium), mineral waters, and precious stones (quartz, garnet, allanite, kyanite, fluorite, feldspar, microlite, apatite, beryl, columbite, and helvite).

IRON ORES AND PIG IRON.

The present commercial deposits of iron ore in Virginia are confined to the Piedmont and Appalachian regions. The iron ores of the Piedmont region occur in metamorphic crystalline rocks of unknown age, probably pre-Cambrian in large part; those of the Appalachian region occur in sedimentary rocks of Paleozoic age, or the residual material derived from them.

The iron minerals used as ores of the metal in the State are, chemically, oxides, of which there are three important types, limonite (brown hematite), red hematite, and magnetite. Of these, the brown hematite has been and is the principal source of the metal, as indicated

^aA map of Virginia showing location of mines and quarries was published by the State Geological Survey in 1909 and partly distributed with Bull. No. I-A. Scale of map, 12 miles equals 1 inch.

in the table on page 21. The sulphides and carbonate, especially the former, occur in many places, but they do not form as yet an important source of the metal.

The iron ores of Virginia may be classified as follows:^a

PIEDMONT REGION:

1. Hematite. Specular hematite associated with magnetite in the James River valley.
2. Brown ore. Gossan ore forming a capping of pyrrhotite deposits in southwestern Virginia, and pyrite deposits in northern and central Virginia.
3. Magnetite. Associated with gneisses, schists, and crystalline limestones, in central and southwestern Virginia, and with basic intrusions in the Blue Ridge.

APPALACHIAN REGION:

1. Hematite.
 - (a) Siliceous specular hematite interbedded with lower Cambrian shale and quartzite in the Blue Ridge.
 - (b) Fossil (red) hematite interbedded with shale and sandstone of Clinton (Rockwood) formation in western and southwestern Virginia.
2. Brown ore.
 - (a) "Mountain" ores of the Blue Ridge and the New River district, associated with lower Cambrian quartzite and with residual material above it derived from the quartzite and from the overlying formations.
 - (b) "Valley" ores associated with residual material of the Shady limestone in the New River district. A few deposits of this nature occur with other limestones of the Shenandoah group along the Blue Ridge.
 - (c) Oriskany ores replacing the Lewistown limestone directly under the "Monterey" (Oriskany) sandstone in the western part of the Appalachian region.
3. Magnetite. Magnetite and hematite associated with limonite and iron carbonate in the upper part of the Shenandoah group locally in southwestern Virginia.
4. Iron carbonate. Iron carbonate occurring with limestone magnetite in the upper part of the Shenandoah group locally in southwestern Virginia, and as ironstone concretions in the Martinsburg and Romney shales.

In recent years, the iron ores of the Piedmont region have contributed only a very minor part of the total production of the ores in the State, though small quantities of magnetite and limonite (brown ore) are produced annually from this region.

Magnetite deposits, usually having the form of lenticular beds or elongated pods and interlaminated with gneisses, schists and, in places, limestones, are widely distributed through the Piedmont region.

^aHarder, E. C. Bulletin 380, U. S. Geological Survey, 1909, pp. 216-217. The sulphide types of iron ores are omitted from the scheme of classification, as they have not yet contributed to the production of metal in Virginia, but are utilized in acid making, and are treated under Pyrite and Pyrrhotite on pages 108-111.

They occur in Albemarle, Amherst, Appomattox, Buckingham, Fluvanna, Franklin, Grayson, Louisa, Nelson, Patrick Henry, and Pittsylvania counties. The James River valley area below Lynchburg was a principal iron-producing district in the State about a hundred years ago, and was exploited again about 1880. In recent years, the magnetite ore at Pittsville in Pittsylvania County has been the most extensively mined in the Piedmont region. The ore body has a thickness of 12 feet and occurs between crystalline limestone and mica schist. Magnetite has been mined near Rocky Mount, in Franklin County, and west of Goblintown Creek in Patrick County. The magnetite deposits vary in thickness up to 30 feet and more, and they show much irregularity (pinching and swelling) on both the strike and the dip. They vary greatly in composition, from bodies containing practically all iron ore to those made up largely of gangue minerals with but little ore. They include both non-titaniferous and titaniferous types.

Brown (gossan) ore, resulting from the oxidation of pyrite and pyrrhotite above groundwater level, has wide distribution through the Piedmont region. It occurs capping the pyrite bodies in metamorphic crystalline schists of unknown age, of Buckingham, Louisa, Prince William, Spottsylvania, and Stafford counties, and formed the basis for the first iron industry in Virginia; but it has not been mined in recent years. Similar ore occurs in Carroll, Floyd, Franklin, and Grayson counties, forming the capping of pyrrhotite deposits in metamorphic crystalline schists.

The "Great Gossan Lead" of Carroll-Floyd-Grayson counties is the most extensive one of the gossan leads. It is quite variable in width, ranging from a few feet up to more than 150 feet. The gossan consists of light brown or yellow limonite, which extends to a depth of from 10 to 60 feet, and has been mined in many places.

The brown iron ores of the Appalachian region, which include the "mountain," valley or limestone, and Oriskany ores, are commercially the most important ores in Virginia. The specular hematites of the Blue Ridge are second in importance, the Clinton fossil ores third, and the remaining types are of minor importance. These types of ores are briefly described below.

Specular hematite occurs in workable quantity along the Blue Ridge in Bedford, Botetourt, and Roanoke counties. It occurs interbedded with lower Cambrian quartzite and shale, and is believed to be sedimentary in origin. The ore bed is of variable thickness and has been worked at eight localities, as follows:^a "The Arcadia and Wood mines, about 4 miles southeast of Buchanan; the Ironville and Dewey mines, near Montvale; the Lemon, Grubb-Specular and Edith mines, about 3 miles northwest of Blue Ridge Springs; and the Griffin-Specular mine, about 5 miles south of Roanoke. Of these, the Arcadia, Wood, Dewey, and Edith mines are at present in operation." The ore is a very siliceous dark-red hematite, in which the iron content ranges from less than 35 per cent to 45 per cent, and the silica content from 30 to 40 per cent.^b

Fossil hematite, interbedded with shale and sandstone of the Clinton (Rockwood) formation of the Silurian system, occurs in workable quantity in Alleghany, Lee, and Wise counties. In Alleghany County, fossil ore has been mined on the southeast slope of Horse Mountain, 3 miles southeast of Lowmoor, and in the bluff northeast of Jackson River at Iron Gate. Only one workable bed of ore is known, which averages less than two feet in thickness. The ore mined is of the soft variety from which the calcium carbonate has been removed by surface waters, and it carries 46 to 57 per cent of metallic iron. According to Hayes,^c nearly 90,000 tons of fossil ore were shipped in 1907 from mines in the Alleghany County district.

In the Lee-Wise counties district of southwest Virginia, fossil hematite ore is mined south of Big Stone Gap on Wallen Ridge, and in Powell Valley, and southwest of Pennington Gap along Poor Valley ridge. The Yearly, Irondale, Keystone, and Oreton mines have been opened south of Big Stone Gap, and the Pennington, Lavine, Ben Hur, Truro, Noes Siding, Grabill, Boones Path, and Ewing mines are opened along Poor Valley ridge. In the southwest Virginia district there are three ore beds which have been mined, ranging in thickness

^aHarder, E. C. Bulletin 380, U. S. Geological Survey, 1909, p. 225.

^bIbid., pp. 227 and 228.

^cHayes, C. W. Bulletin 394, U. S. Geological Survey, 1909, p. 88.

from 6 inches to 2.5 feet. The ores mined are chiefly of the soft variety, and are of lower grade than those of the Alleghany County district.

The "mountain" brown ores, so called because of their occurrence along the flanks or at the base of a sandstone or quartzite ridge, extend along the west slope of the Blue Ridge from near Front Royal, in Warren County, to a point south of Roanoke, and along the east side of the New River-Cripple Creek district, in Pulaski County, and along and near to the Wythe-Carroll counties boundary. The ore deposits are associated with Cambrian quartzite or its residual material, usually the latter, show great variation in form and texture, and range in iron content from 35 to 50 per cent and in silica content from 10 to 30 per cent, with usually high manganese and phosphorus. They are of lower grade than the valley or limestone brown ores, and are regarded as concentrations by meteoric water, the iron having been derived largely if not entirely from the overlying shale and limestone formations.

The valley or limestone brown ores are distributed at intervals throughout the Valley region west of the Blue Ridge, in association with the residual clays derived from the limestone by processes of decay. The principal occurrence of these ores is in the New River-Cripple Creek district of Wythe and Pulaski counties, in residual clays derived from the Shady (lower member of the Shenandoah group) limestone. A large number of mines have been operated in this district.

In the northern and central Valley region the limestone brown ores are not so abundant, there being less than a dozen deposits that have been worked between Roanoke and the Maryland boundary. The ores of this region, called the Blue Ridge belt, occur in residual clays derived from the Natural Bridge limestone.

The ore is disseminated through the residual clay in varying concentrations ranging from large porous masses down to pellets the size of a pea. The proportion of clay to ore in the workable deposits varies considerably, usually from 5 to 1 to 25 to 1.^a The ores are usually richer than the "mountain" ores ranging in iron content from 40 to 55

^aHarder, E. C. Bulletin 380, U. S. Geological Survey, 1909, p. 244.

per cent, and in silica content from 5 to 20 per cent, with usually less than 1 per cent of manganese and enough phosphorus to be classed as a non-Bessemer ore.

The valley or limestone brown ores are residual deposits, the iron of which was originally disseminated through the rocks and, under favorable conditions, has been concentrated during the process of weathering and erosion.

The Oriskany brown ores are the most important of the iron ores mined at present in Virginia. The principal district of Oriskany ores includes the counties of Alleghany, Botetourt, and Craig, from which nearly all the ore mined of this type is produced. Minor deposits occur on Draper Mountain, in Pulaski and Wythe counties; on Peters Mountain, Giles County; in the Buffalo Gap area, Augusta County; in Massanutten Mountain, Shenandoah County; and on North Mountain, in Shenandoah and Frederick counties.^a

These ores are limited to a definite horizon, in the Lewistown (Helderbergian) limestone, immediately below the Monterey (Oriskany) sandstone. They represent replacements of the upper portion of the limestone. The ore was derived from the overlying Devonian black shales by meteoric waters. Where the shales were of sufficient thickness and the underlying Monterey sandstone sufficiently thin and fractured, the iron-bearing solutions penetrated into the underlying limestone and, under favorable conditions, replaced the calcium carbonate by iron oxide, forming the ore bodies.

The ore deposits are continuous for considerable distances along the strike with great variations in thickness of the ore bodies shown, ranging up to 75 feet with a probable average of 15 to 25 feet. The ore, usually fairly solid but frequently porous with the cavities containing clay, ranges between 35 and 50 per cent of metallic iron. They are usually high in silica and manganese, resembling in this particular the "mountain" ores.

The principal Oriskany brown ore mines^b in the State are Liberty and Van Buren Furnace mines, in Shenandoah County; the Buffalo Gap and Ferrol mines, in Augusta County; the Victoria and Longdale mines, north of Longdale, Alleghany County; the Dolly Ann,

^aHarder, E. C. *Ibid.*, p. 246.

^b*Op. cit.*, p. 248.

Iron Mountain, and Stack mines, near Covington, Alleghany County; the Lowmoor and Rich Patch mines, near Lowmoor, Alleghany County; the Jordan mines, on Potts Creek, Alleghany County; the Callie, Wilton and Circle mines, near Glen Wilton, Botetourt County; the Oriskany and Fenwick mines, in Botetourt and Craig counties, near Oriskany; the Gala mines, near Dagger Spring, Botetourt County; the Clayton and Peak Knob mines, near Pulaski, Pulaski County; and the Locust Hill mine, near Max Meadows, Wythe County.

The remaining types of Appalachian iron ores in Virginia, including the limestone magnetite and iron carbonate ores, are of minor importance. The principal deposits of the limestone magnetite ores, so far known, occur near Big Sandy Junction, in Giles County, and near Abingdon, in Washington County, with smaller deposits elsewhere in southwest Virginia. Iron carbonate is reported in minable quantity from only one locality, namely, near Abingdon, in Washington County, in association with limestone magnetite ore.

The iron ores of the State are under investigation by the Virginia Geological Survey, after the completion of which a detailed report will be published.

The iron ore mining industry in Virginia showed a decided increase in 1909, the figures of production being 837,847 long tons, valued at \$1,693,188, as against 692,223 long tons, valued at \$1,465,691 in 1908. This was an increase over the 1908 production, of 145,624 long tons or 21.03 per cent in quantity, and \$227,497 or 15.52 per cent in value. The average price per tone of ore in 1909 was \$2.02.

The production of iron ores in Virginia during 1910 amounted to 903,377 long tons, valued at \$1,845,144. These figures represent an increase over the production for 1909, of 65,530 long tons or 7.82 per cent in quantity, and \$151,956 or 8.97 per cent in value. The average price per ton of the iron ore mined in Virginia during 1910 was \$2.04. The 1910 production of iron ores in the State represented the output of forty-nine mines distributed among fourteen producers operating in the same number of counties (14). The counties producing iron ore

in the State during 1910 were as follows: Alleghany, Augusta, Bedford, Botetourt, Carroll, Craig, Lee, Pittsylvania, Pulaski, Roanoke, Rockbridge, Smyth, Washington, and Wythe.

There is given in the table below the total production of iron ore in Virginia by varieties, from 1900 to 1910, inclusive. It will be observed that brown hematite is vastly the most important, producing at present 90.89+ per cent of the total. The next in order of importance is red hematite, which contributed, in 1910, a little over 9 per cent of the total production, while magnetite for the same year amounted to less than a half of one per cent.

Production of Iron Ore in Virginia, by Varieties, 1900-1910, in long tons.

Year	Brown hematite	Red hematite	Magnetite	Total quantity	Total value
1900 ^a	918,157	3,664	.....	921,821	\$1,489,318
1901 ^a	910,214	13,156	2,024	925,394	1,466,423
1902 ^a	953,128	31,677	3,153	987,958	1,667,456
1903 ^a	764,948	31,609	4,604	801,161	1,432,624
1904 ^a	528,853	17,952	3,448	550,253	951,478
1905	704,470	35,357	518	740,345	1,256,428
1906	735,204	92,257	620	828,081	1,579,817
1907	696,518	89,867	471	786,856	1,538,920
1908	626,910	64,323	990	692,223	1,465,691
1909	762,937	72,955	1,955	837,847	1,693,188
1910	821,131	81,647	599	903,377	1,845,144

^aIncludes West Virginia, but practically the total production was from Virginia.

A good idea of the distribution of the different varieties of iron ore produced in Virginia in 1910 may be gained from the table below, in which the total production is classified by varieties and counties. Brown hematite, which constitutes at present the chief ore, comes mostly from the Appalachian counties west of the Blue Ridge, with only a minor production from the counties in the crystalline area. The same is true for the production of hematite, which now stands next in importance to brown hematite. Deposits of magnetite are widely distributed through the crystalline area, which form important reserves of iron ore, but the production of magnetite in the State has been very small and of minor importance.

*Production of Iron Ore in Virginia, by Counties and Varieties, 1910,
in long tons.*

County	Brown hematite Long tons	Value	Red hematite Long tons	Value
Alleghany	234,772	\$ 582,068	(a)	(a)
Augusta	147,298	272,768	(a)	(a)
Bedford				
Carroll				
Craig	168,148	398,928	(a)	(a)
Botetourt				
Lee .....	.....	.....	(a)	(a)
Pittsylvania	127,185	202,099		
Pulaski				
Roanoke				
Smyth	14,001	31,216		
Rockbridge				
Washington	130,326 ^b	215,939		
Wythe				
Total.....	821,730	\$1,703,018	81,647	\$ 142,126

^aIncluded under total in order to avoid disclosing individual production.

^bIncludes 599 tons of magnetite.

The average price per long ton of the different varieties of iron ore produced in Virginia during 1910 follows: Brown hematite \$2.07, red hematite \$1.74, and magnetite \$1.50. These prices represent the value of the ore at the mouth of the mine, and are taken directly from the replies of the producers.

The production of pig iron in Virginia during 1909 amounted to 391,134 long tons, valued at \$5,550,000, as compared with 320,458 long tons, valued at \$4,578,000 in 1908, an increase in quantity of 70,676 long tons or 22.05 per cent, and in value of \$972,000 or 21.21 per cent. The 1910 production of pig iron in Virginia amounted to 444,976 long tons, valued at \$6,150,000, an increase over the production of the preceding year of 53,842 long tons in quantity, and \$600,000 in value.

There is given in the table below the production of pig iron in Virginia for the years 1905 to 1910, inclusive.

Production of Pig Iron in Virginia, by years, 1905-1910.

Year	Quantity Long tons	Value	Value per ton
1905	510,210	\$7,540,000 ^a	\$14.78
1906	483,525	8,591,000 ^a	17.77
1907	478,771	8,963,000	18.72
1908	320,458 ^b	4,578,000	14.29
1909	391,134 ^b	5,550,000	14.19
1910	444,976 ^b	6,150,000	13.82

^aEstimated.^bBirkinbine, J. Personal communication.

LIST OF IRON ORE OPERATORS

OPERATOR	OFFICE.	MINE
Barr Ore & Iron Corporation.....	Pittsville	Pittsville.
Bentonville Mining Co.....	Philadelphia, Pa	Bentonville
Black, H. A and J. L.....	Staunton	Stuarts Draft
Bland Iron & Coal Co.....	Wytheville	Bland County
Boone's Path Iron Co.....	Baltimore, Md	Rose Hill Station
Botetourt Mineral & Mining Co.....	Fincastle	
Buena Vista Iron Co., Inc.....	Johnstown, Pa	Buena Vista
Catawba Mining & Manufacturing Co.....	Roanoke	
Coots, Graham	Basic City	Staunton
Crescent Iron Ore Co.....	New York, N. Y.....	Stanley and Stanleyton
Crowder, Delaney & Miller.....	Covington	Clifton Forge
Elliotts Knob Coal & Iron Co.....	Buffalo Gap	
Eureka Manganese Co.....	Stanleyton	Stanleyton
Franklin, G. H.....	Brights	Brights
Goshen Iron Co., Lessee, Chapman Iron, Coal & Coke Co.....	Goshen	Clifton Forge
Graham Heirs, Part Owners of Virginia Iron, Coal & Coke Co.....	Graham Forge	
Halser, Ira F.....	Troutville	Troutville
Hatcher & Sheaffer.....	Pulaski	Peak Knob and Pulaski
Horneck Construction Co.....	Cumberl'd Gap, Tenn.....	Ben Hur and Jonesville
Indian Camp Mining Co.....	Max Meadows	Ivanhoe
Ivanhoe Furnace Co.....	Pittsburg, Pa.....	{ Abingdon Austinville Fries Ivanhoe
Keystone Coal & Iron Co.....	Philadelphia, Pa	Oreton
Laing, J. B.....	Lewisburg, W. Va., or Newcastle.	
Little, J. F.....	Newcastle	Waitsville
Lobdell Car Wheel Co.....	Wilmington, Del	White Rock Furnace
Longdale Iron Co.....	Longdale	Australia
Lowmoor Iron Co. of Virginia.....	Lowmoor	Backbone, Covington, Lowmoor, and New- castle
McLean, James G.....	Pittsburg, Pa.....	Raphine
Manganese Iron & Coal Co.....	Newcastle	Newcastle
Oriskany Ore & Iron Corporation, Lessees Alleghany Ore & Iron Co.....	Iron Gate	Lignite and Vesuvius

OPERATOR	OFFICE	MINE
Persinger, J. W.	Buena Vista	Rich Patch
Pittsville Mining Co.	Pittsville	Pittsville
Poplar Camp Mining Co.	Max Meadows	Ivanhoe and Max Meadows
Princess Furnace Co.	Glen Wilton	Glen Wilton
Pulaski Iron Co.	Pulaski	Allisonia, Buchanan, Cripple Creek, Foster Falls, and Pulaski
Sanders & St. Clair.	Troutville	Troutville
Scherr, A. C. and others.	Charleston, W. Va.	Grottoes
Seibel, H. J.	Happy Creek	Happy Creek
Spoor, W. M.	Abingdon	Adwolf
Thrush, H. H.	Front Royal	Limeton
Union Iron & Steel Co., L. O. Pettit, Receiver	Big Stone Gap.	Ewing
Utah-Virginia Mining Corporation.	Salt Lake City, Utah.	Troutville
Vesuvius Mining Co.	Baltimore, Md	Greenville
Virginia Clay & Material Co.	Farmville	Farmville
		Allisonia
		Baker Mines
		Barren Springs
		Blue Ridge Springs
		Clark Summit
		Cotopaxi
		Cripple Creek
		Foster Falls
Virginia Iron, Coal & Coke Co.	Roanoke	Graham
		Interior
		Max Meadows
		Montvale
		Ogden
		Reed Island
		Roanoke
		Speedwell
Virginia Iron & Lumber Co.	Philadelphia, Pa	
Virginia Ore & Iron Co.	Baltimore, Md	Berryville
Watts, Sterling	Max Meadows	Austinville
West End Furnace Co.	Roanoke	Allisonia
Williams & Son, John T.	Bristol, Va.-Tenn	Bonsacks
Willis & Nutson	Hamakertown	
Wissler Mining Co.	LaFollette, Tenn	Ivanhoe
Zinns Iron Mining Co.	Washington, Pa.	Vesuvius

MANGANESE ORES.

Virginia has more known deposits of manganese, they extend over a larger territory, a larger number of localities have been worked, and more manganese has been produced than in any other state in the Union. Manganese ores occur in each of the three major geologic provinces of the State, namely, the Coastal Plain or Tidewater belt, the Piedmont province or crystalline area, and the Appalachian Mountains province or Paleozoic area. Of these the Mountain (Valley) province has yielded the principal production, with extensive operations and a large total production from the Piedmont province. Only

a slight production has come from the eastern or Coastal Plain province.

Manganese occurs natively in a variety of mineral combinations but only the oxides of the metal are of commercial importance in Virginia. Of these, pyrolusite and psilomelane greatly predominate with, in places, much of the earthy oxide, wad. These different oxides often occur admixed in varying proportions. The ore is frequently partially or entirely crystalline, of a dark steel-blue color, and the nodular (kidney) type, which usually prevails, often displays the complete or partially layered structure of concretionary masses.

The manganese ores are usually found imbedded in the residual clays which overlie the rocks, from which the clays have been derived by the usual processes of decay. The underlying rock yielding the ore-bearing clays may be of sedimentary or igneous origin, and may be the usual consolidated sediments, or a metamorphic crystalline type.

The ore is distributed through the clays in an irregular manner in the form of pockets or lenticular masses, rarely as distinct beds; as veinlets and stringers cutting the clays in all directions; as single nodules and masses, ranging in weight up to 500 pounds, assembled in the clays; as small disseminated grains scattered through the clays; as breccia ore in large masses; and as probable replacement and cavity fillings in sandstone or sandy clay. In places, both in the Piedmont and Valley regions, the ore distribution conforms in a general way to the bedding of the inclosing clays; frequently, however, this is obscured and the ore bodies indiscriminately cut the clays in all directions.

In the Piedmont region where the residual clays have been derived from the decay of crystalline schists, and the original schistosity of the rocks preserved in the clays, the ore frequently conforms with the foliation and is disposed in thin stringers and sheets much after the manner of interleaving. The pockets show much variation in size and number, ranging from small nests to bodies yielding many tons of ore. They are rarely composed of solid ore free from clay, but the ore forms thickly-studded nodules in the clays. The pockets may be closely spaced or they may occur at wide intervals, usually not connected,

although at times stringers or irregular nodules may lead from one pocket to another.

The principal productive manganese deposits in Virginia are (1) those of the Piedmont region, occurring chiefly in Campbell and Nelson counties, northeast and south of Lynchburg; and (2) those of the Valley region occurring along the west slope of the Blue Ridge. Numerous mines have been worked in the Piedmont region.

In the Valley region the principal manganese ore belt lies along the west slope of the Blue Ridge. Workable deposits of manganese ores have been found in each county bordering on the western slope of the Blue Ridge. The Blue Ridge iron ore mines occur along this belt, many of which contain some manganese in the form of manganese iron ore, and similarly many of the manganese deposits contain some iron. The manganese ores are usually found embedded in residual clays derived from Cambrian ferriferous shales, which overlie the Cambrian quartzite. In other places over the Valley region, manganese ores occur similarly embedded in residual clays derived from limestone of Cambro-Ordovician age. The famous Crimora mine in Augusta County has produced more manganese ore than all other mines in the United States combined.

Virginia has always been the principal producer of manganese ores in the United States. The figures of production in 1909 were 1,334^a long tons, valued at \$14,275, as compared with 6,144 long tons, valued at \$62,776 in 1908. This represents a loss of 4,810 long tons, or 78.3 per cent, in quantity, and \$48,501, or 77.25 per cent, in value. There were 2 producers of manganese ores in 1909, operating in 2 counties. The production for 1910 was as follows: 2,059^a long tons, valued at \$18,509. These figures represent an increase, over the 1909 production, of 725 long tons in quantity, and \$4,234 in value. There were four producers of manganese ore in 1910, and one of manganese ore. The production came from the following four counties: Augusta, Campbell, Rockingham, and Warren. In addition to the figures given above, 2,085 long tons of manganese ore were reported as stock on hand at the close of 1910.

There are given in the table below the figures of production and value of manganese ores in Virginia from 1903-1910, inclusive.

^aIncludes small production of manganese ore.

Production and Value of Manganese Ores in Virginia, 1903-1910.

Year	Quantity Long tons	Value	Average value per ton
1903	1,801	\$ 19,611	\$10.89
1904	3,054	28,406	9.30
1905	3,947 ^a	35,209	8.92
1906	6,028	77,522	12.86
1907	4,604	56,469	12.27
1908	6,144 ^b	62,776	10.22
1909	1,334 ^c	14,725	10.70
1910	2,059 ^c	18,509	8.98

^aIn addition, 453 tons of tailings, valued at \$406, were shipped.

^bIn addition, 274 tons of manganiferous iron ore were sold.

^cIncludes small production of manganiferous ore.

LIST OF MANGANESE ORE OPERATORS

OPERATOR	OFFICE	MINE
Atkins, Geo. M.	Attoway	Attoway
Bear Pond Lumber, Coal & Oil Co.	Gettysburg, Pa.	Capon Roads
Benham, Wm. J.	Philadelphia, Pa.	Woodstock
Binswanger & Co., H. P.	New York, N. Y.	Woodstock
Cameron, Donald	Baltimore, Md.	Woodstock
Carnahan, J. W.	Wytheville	Rural Retreat
Cole, Hugh F.	Chilhowie	Chilhowie
Cook & Son Mining Co., D. S.	Wrightsville, Pa.	Gala
Cox, Charles W., Assignee, Henry W. Poor & Co.	New York, N. Y.	Crimora
Cuthbert, W. R.	Lynchburg	Evington
Dry Run Mining & Development Co.	Norfolk	Compton
Eagle Cliff Mining Co.	Atkins, R. F. D. No. 2.	Ivanhoe
Etna Iron & Manganese Co.	Lynchburg	Mt. Athos
Eureka Manganese Co.	Stanleyton	Stanleyton
Evington Manganese Co.	Evington	Evington
Forney Mining Co.	Roanoke	
Harmon, C. H., Prop., Magie, H. M., Op- erator	Waynesboro	Crimora
Lackey, L. B.	Happy Creek	Happy Creek
Lang, S. J.	Harrisonburg	Middle River District
Loeb, Simon F.	McKeesport, Pa.	Otter River
McCormick, F. Olney	Philadelphia, Pa.	Zepp
McCune, Samuel	Meadow Mills	Cedar Creek
McGovern, Wm., B. F. Buchanan, Lessee.	Bristol, Tenn.	Sugar Grove
Main, T. F.	Wytheville	Wytheville
Manganese Corporation of Virginia.	New York, N. Y.	Vesuvius
Marchant, E. W.	Attoway	Marion
Metal Manufacturing Co.	Elkton	Elkton
Metallic Alloys Co.	New York, N. Y.	Lyndhurst
Midvale Mining Co., Inc., F. W. Schultz, Operator	Baltimore, Md.	Midvale
National Manganese Corporation.	Washington, D. C.	Lyndhurst
Piedmont Manganese Co.	Lynchburg	Mt. Athos
Pittsville Mining Co., E. R. Hutter, Pro- prietor	Pittsville	Pittsville
Poor & Co., Henry W.	New York, N. Y.	Crimora
Rockingham Mineral Co., Inc.	Elkton and Pittsburg, Pa.	Elkton
Seibel, H. J., Jr., Prop., and Lackey, L. G., Supt.	Philadelphia, Pa., and Happy Creek	Happy Creek
Southern Manganese Mining Co.	Harrisonburg	Front Royal
Staley's Creek Manganese & Iron Co.	Marion	Currin Valley
Steele Ore Co., care Royal Baking Powder Co.	New York, N. Y.	Stuarts Draft
Stoner, K. B.	Pincastle	Troutville
Tate, James, D.	Chilhowie	Marion
Weightman, Wm. (Hampton L. Carson, Attny. for Anne M. Walker)	Philadelphia, Pa.	Mt. Athos

GOLD AND SILVER.

The Virginia Mining Company of New York, operating between the years 1831 and 1834 the Grasty tract of land in Orange County, was the first gold mining company incorporated in Virginia. In 1836, there was considerable activity in gold mining in the State, and the production was reasonably steady from the rediscovery in 1831 to 1850, the annual value being given between \$50,000 and \$100,000. Increased activity in gold mining in the State was manifested in the early fifties, but the Civil War almost completely stopped mining operations in Virginia and in the South generally. Considerable activity was again manifested in the Virginia gold fields after the close of the Civil War, and milling and reduction plants were erected at various points. Many of these attempts met with only small success and in most cases were abandoned, not because of the lack of ore, but because largely of bad management and inexperienced mining, together with a change from free milling to pyrite ores.

The principal gold-bearing areas are arranged in a belt which begins in Montgomery County, Maryland, and extends across Virginia in a southwestward direction to the North Carolina line. The belt varies in width from 15 to 25 miles, and is 200 miles long, with its best developed portion in Fauquier, Stafford, Culpeper, Orange, Spottsylvania, Louisa, Fluvanna, Goochland, and Buckingham counties. Gold is also found in Appomattox, Prince Edward, Charlotte, Halifax, and Pittsylvania counties, which mark the southwest extension of the principal belt. Excepting Halifax, which has been a producer for several years, no developments have been made in the last-named counties.

A smaller belt occurs on the west side of the Blue Ridge in Montgomery, Floyd, and Grayson counties, but is undeveloped and has proved of little economic importance.

Many of the mines in the principal belt have produced large quantities of gold, as shown in the United States mint returns, and have been rather extensively worked. Preparations are in progress for the resumption of mining at a number of the mines in the principal belt. During 1910 considerable interest was manifested at many

places within the belt in exploiting old and new properties. The principal gold belt is crossed by innumerable streams bordered by placers, many of which have been worked over several times.

The principal rocks of the gold belt are micaceous schists and gneisses, often garnetiferous and chloritic, and in places hornblendic. They include both altered sediments and igneous masses. The prevailing strike is N. 20° E., and the dip is toward the east and southeast at varying angles, frequently steep, and in many cases nearly vertical. Granite masses and basic igneous rocks occur in the region, sometimes sheared from dynamic causes.

The gold-bearing veins are chiefly quartz, which vary in texture from large crystalline masses to very fine saccharoidal grains. In structure, they vary from massive to thin platy or schistose bodies, both usually penetrated by closely spaced irregular fractures. The principal metallic content is auriferous pyrite, which at times is copper-bearing and contains more or less admixed chalcopyrite. Within the weathered zone, extending from the surface down to local water-level and of varying depth, the quartz is more or less porous and discolored or stained with iron oxide from the oxidation of the sulphide minerals, and the liberation of free or elementary gold. Below the local water-level the veins are fresh, the sulphides are unaltered, and elementary gold is less frequent in occurrence. The early operations were confined largely to the oxidized portions of the veins which yielded a free-milling ore that was easy of treatment. Since then, operations chiefly include the mining of sulphurets or the sulphide bodies, which require a different metallurgical treatment of the ores in order to extract and recover the gold.

The gold-bearing veins conform in the main to the structure, strike and dip of the inclosing rocks, a fact which has caused various explanations to be advanced for their origin by different observers. Although the veins conform in the main to the dip and strike of the inclosing rocks, the correspondence is far from being exact, for they frequently cut the schists at small angles both in dip and strike.

Excepting quartz and pyrite, the gangue minerals in the gold veins of Virginia comprise the following species: Chalcopyrite, native copper, galena, mispickel (arsenopyrite), pyromorphite, tetrahedrite,

tourmaline, vanadinite, sphalerite, pyrrhotite, and siderite. So far as the gangue minerals are concerned, the Virginia gold ores are entirely typical in character. The ores are quartzose deposits in which pyrite is usually present, chalcopyrite common, and mispickel and sphalerite are not rare.

In 1904, the production of gold and silver in Virginia was contributed to by eleven counties. From the United States mint returns for 1905, the gold production in Virginia increased in value, over 1904, \$1,182; and silver decreased \$3,779. In 1905, seven mines were reported producing, three of which were placer mines. According to Lindgren, the four deep mines yielded an estimated tonnage of 800, with an average value of \$5.35 per ton in gold and silver. The production in 1906 showed an increase over that of 1905 of \$9,850 in gold and \$61 in silver. There were 9,565 short tones of siliceous ores raised which yielded an average extraction of \$4.17 per ton. There was no reported production for the year from placer mines. In 1907, the total production of gold was valued at \$8,288 and of silver \$146, a decrease from that of 1906. According to McCaskey, seven mines reported a production, six of which were deep mines, yielding 26,822 short tons of ore. Of this, 1,128 short tons were siliceous ores which yielded an average extraction of \$7.33 per ton in gold and silver; 25,044 short tons were siliceous and cupriferous sulphide ores, giving an extraction of \$0.002 per ton in the precious metals; and the remainder were lead ores which yielded no gold or silver.

Four placers and four deep mines reported a production in 1908. According to McCaskey, the deep mines reported 12,877 tons of ore, 230 tons of which were siliceous gold ores, with an average value in precious metals of \$7.135 per ton, and 1,896 tons were copper ores yielding \$0.05 in precious metals and 12.4 pounds of copper per ton. Eight hundred (800) tons of lead ores yielded gold and silver valued at \$0.28 and 95.2 pounds of lead per ton.

Virginia produced, in 1908, 118.57 fine ounces of gold valued at \$2,451, and 236 fine ounces of silver valued at \$125. This shows a decrease from the production of 1907 in gold of 283.43 fine ounces in quantity, and of \$5,849 in value, and a decrease in silver of \$21 in value, but an increase of 15 fine ounces in quantity. In 1909, the

total production of gold was 181.41 fine ounces valued at \$3,750, and of silver 4,825 fine ounces valued at \$2,509, an increase in value over that of 1908 of \$1,299 of gold and \$2,384 of silver. Eight mines contributed to the production, five of which were placers and three deep mines. According to McCaskey, the deep mines yielded 14,075 tons of ore, 250 tons of which were siliceous gold ore of an average value of \$2.09 per ton, and 13,825 tons were copper ores and pyrite cinder yielding 35 cents in precious metals and 16.2 pounds of copper per ton.

In 1910, the production of gold and silver in Virginia showed a marked decrease over that of 1909. The total production of gold was 42.96 fine ounces valued at \$888, and of silver 128 fine ounces valued at \$69.

There is given in the table below, compiled from the production reports of the United States Mint and Mineral Resources of the United States, the production of gold and silver in Virginia by years.

Production of Gold and Silver in Virginia by years.

Year	Value	Year	Value
1799-1879.....	\$3,091,700	1895.....	\$ 6,325
1880.....	11,500	1896.....	4,466
1881.....	10,000	1897.....	Not given.
1882.....	15,000	1898.....	4,500
1883.....	7,000	1899.....	7,160
1884.....	2,500	1900.....	3,200
1885.....	3,500	1901.....	5,720
1886.....	4,000	1902.....	6,227
1887.....	14,600	1903.....	18,630
1888.....	7,500	1904.....	7,686
1889.....	4,113	1905.....	5,122
1890.....	6,496	1906.....	15,000
1891.....	6,699	1907.....	8,434
1892.....	5,002	1908.....	2,576
1893.....	6,190	1909.....	6,259
1894.....	7,643	1910.....	957

In the subjoined table are given the quantity and value of gold and silver produced in Virginia for the years 1906, 1907, 1908, 1909, and 1910.

Production of Gold and Silver in Virginia by years, 1906-1910.

Year	Gold		Silver	
	Quantity in fine ozs.	Value	Quantity in fine ozs.	Value
1906.....	717.50	\$14,832	250	\$168
1907.....	400.93	8,288	221	146
1908.....	118.57	2,451	236	125
1909.....	181.41	3,750	4,825	2,509
1910.....	42.96	888	128	69

COPPER.

Copper ores are found in many counties of the State and in a variety of occurrences. They are confined to the crystalline rocks of the Piedmont Plateau and the Blue Ridge Mountains, and to the Triassic red beds, which form numerous small areas in the Piedmont province:

The known geographic areas of these ores in the State are:

I. THE PIEDMONT REGION:

- (1) The Virgilina district, which includes Halifax and Charlotte counties in Virginia, and Person and Granville counties in North Carolina.
- (2) The deposits on or near Southwest Mountain in Albemarle County, and those near New Canton, Arvonias, and Dillwyn, in Buckingham County.
- (3) The pyrite bodies in Louisa, Stafford, and Prince William counties, mined principally for their sulphur content, but carry at times sufficient copper to warrant saving.

II. THE NORTHERN BLUE RIDGE REGION:

Includes those deposits from near Front Royal southward, embracing parts of Warren, Fauquier, Rappahannock, Madison, Page, and Greene counties.

III. THE SOUTHWEST VIRGINIA REGION:

Includes the "Gossan Leads" of the Floyd-Carroll-Grayson counties plateau.

IV. THE TRIASSIC AREAS:

Includes deposits chiefly in Loudoun, Culpeper, and Orange counties.

Geologically, the copper ores are confined to the crystalline rocks, either the schists or gneisses or the massive igneous rocks of the Piedmont and Blue Ridge provinces, and to the red shale-sandstone series

of the Triassic areas. In the Virgilina district, the ores occur in quartz-fissure veins which intersect or lie in an altered andesite and associated tuffs of probable pre-Cambrian age. The ores of the northern Blue Ridge region are segregated in and disseminated through basaltic flows of pre-Cambrian age, rocks designated by Keith as Catoctin schist. The "Great Gossan Lead" of the Floyd-Carroll-Grayson counties plateau, in southwest Virginia, is a mineralized faulted zone in schists of doubtful age, probably pre-Cambrian in part. The rocks are in part altered sediments and in part altered igneous masses of basic and acid types, principally the former.

The Virginia copper deposits may be grouped into five types:

- (1) Pyrite masses in schistose rocks worked chiefly for their sulphur content, but containing enough copper in places to be saved. The well-known and extensively worked pyrite bodies near Mineral, in Louisa County, and near Dumfries, in Prince William County, are the best representatives of this type.
- (2) Pyrrhotite veins containing chalcopyrite and some pyrite in schistose rocks referred to usually as the Ducktown, Tennessee, type, the most productive copper district in the South. The best representative of this type in Virginia is the "Great Gossan Lead" in Carroll County.
- (3) The Virgilina type in Virginia and North Carolina which represents quartz-fissure veins carrying chalcocite (copper glance) and bornite (horseflesh ore), with little or no pyrite and chalcopyrite, in volcanic rocks of intermediate character and their associated tuffs.
- (4) The northern Blue Ridge or Catoctin type, the ores of which are chiefly native copper and cuprite with small amounts of the carbonates, azurite and malachite, and very rarely copper sulphides associated with epidote and quartz in a basic volcanic rock, and as grains disseminated through the rock.
- (5) The Triassic type, carbonate, representing sparsely disseminated copper ores, chiefly sulphide, and phosphate of copper, in sandstones and shales of Triassic age.

In addition to these five types, copper in the form of the mineral chalcopyrite is a frequent associate with gold in the gold-bearing quartz-pyrite veins in the principal gold belt of the Piedmont province. Copper has not been observed, however, at any locality within the State in this mode of occurrence to be regarded as of commercial value.

Mining operations for copper in the State have been confined principally to three districts; namely, the Virgilina district, the northern Blue Ridge district, and the "Great Gossan Lead" district. Isolated deposits, which do not properly fall within either of these three districts, have been exploited in a number of localities, confined almost exclusively to the Piedmont counties.

The Virgilina copper district is, commercially, the most important district in Virginia, and the systematic study and detailed mapping on a large scale of the district has been completed by the State Survey, and the report is nearly ready for the press. It is located 47 miles east of Danville on the Atlantic and Danville division of the Southern Railway, and includes a part of Halifax, Charlotte, and Mecklenburg counties.

The principal developments in the district, which include a large number of mines, are confined to an approximate north-south distance of eighteen miles, and an average width of from two to three miles. The present productive portion of the district has about equal extension in the two states, Virginia and North Carolina. The country rock is schist, derived principally from intermediate and acid volcanic rocks and their associated tuffs. The schistosity of the rock strikes N. 10° to 20° E. and dips eastward from 70° to 80° . The quartz veins, of which there are many, are usually more or less parallel, and strike N. 5° to 10° E., with considerable variations from this direction in places. Mining developments show that copper occurs in most of the veins in greater or less quantity. The veins are lenticular bodies of quartz which, in some cases, show very uniform continuous outcroppings at the surface. The workable ores comprise chalcocite or glance (copper sulphide) and bornite (copper-iron sulphide) in a siliceous gangue. Small masses of calcite and feldspar are occasionally noted as gangue minerals. Cuprite (copper oxide), malachite and azurite (green and blue carbonates of copper) occur as alterations of the original sulphides. Some native copper is noted in places. Chalcopyrite and pyrite are almost entirely absent. The worked ores are free from arsenic and antimony, but carry values in both silver and gold, particularly the former.

The "Great Gossan Lead" of Floyd, Carroll, and Grayson counties is a vein traceable for some eighteen miles. It is composed chiefly of pyrrhotite with admixed quartz and schist, and carries streaks and patches of chalcopyrite and pyrite. The vein fills a fault fracture in crystalline schists, varies in width from a few feet to one hundred feet, shows a somewhat variable but average dip of about 45° , and has in general an approximate northeast trend. The region was actively

prospected in the early fifties, and the rich secondary copper ores found beneath the gossan were boxed and shipped to Baltimore. During 1854-5, there were eight producing mines on the "Gossan Lead"; the aggregate amount of ore shipped for the six months from January, 1855, to July, 1855, being 1,454,363 pounds. The ore averaged about 25 per cent copper. The copper content of the sulphide masses is too low (averaging less than 1 per cent metallic copper) to work for copper alone, but the vein is mined on Chestnut Ridge and the ore treated at Pulaski for sulphur, so that the residue is available for copper.

The northern Blue Ridge region, which extends from near Front Royal southward, embracing parts of six counties, has been extensively prospected, and many mines have been developed, but as yet with little production of the metal. The ores of the Blue Ridge region consist chiefly of cuprite and native copper, small amounts of green and blue carbonates, and less of the sulphides, bornite and chalcopyrite. The native copper often occurs as nucleal masses surrounded by cuprite. Bornite is in excess of chalcopyrite. The ore occurs along crevices and joints in small, irregular shaped lenses of quartz, and as disseminated grains through the more epidotized portions of the basalt. It occurs mostly where the rocks are fractured and epidotized. When ore-bearing, the rocks are yellowish green in color, due largely to the formation of epidote and, in part, of chlorite.

During the early part of the last century, attempts were made to mine the sparsely disseminated copper ores in the red sandstones and shales of Triassic age over parts of Loudoun, Culpeper, and Orange counties. While considerable work was done, the ores appear to be too generally diffused in the rocks to be of commercial value. No veins have been found and no well-defined horizons are known, the ores occurring for the most part as films or thin coatings of malachite on the joint surfaces, and as disseminated grains of the sulphide and phosphate of copper through the rocks. Rich specimens of copper glance and copper phosphate are sometimes obtained, but they are by no means abundant.

The production of copper in Virginia during 1909 was 224,162 pounds, valued at \$29,141, as compared with 24,775 pounds in 1908,

valued at \$3,270, an increase of 199,387 pounds in quantity and \$25,871 in value. The production in 1910 showed a marked decrease over that of 1909, amounting in total to 5,402 pounds in quantity, valued at \$686.

LEAD AND ZINC.

Lead mining in Virginia dates back more than 150 years, and the old lead mines at Austinville on New River, in Wythe County, were the first to be worked. For many years after the Virginia mines were operated, mining was confined exclusively to the lead ores. Zinc ores were first discovered at Bertha near Austinville, in Wythe County, during the year 1876. Mining of zinc ores in Virginia dates from the opening of the mine at Bertha in 1879, when a small shipment of ore was made to Providence, Rhode Island. The metal obtained from these ores proved to be of such rare purity that attention was directed at once to them, and a smelting plant was built at Pulaski, which was later remodeled and enlarged, and is owned and operated at present by the Bertha Mineral Company. The "Bertha" spelter is of exceptional purity, and has a world-wide reputation.

Excepting the single deposit in the extreme southwestern part of Albemarle County, the known deposits of lead and zinc in Virginia are limited to the Valley province west of the Blue Ridge. All mining and prospecting for lead and zinc ores in this province have been confined to the western half, extending from and including Roanoke County on the east to and including Scott County on the southwest. Ores of lead and zinc are known to occur either sparingly or in quantity in the following counties: Roanoke, Montgomery, Pulaski, Wythe, Smyth, Bland, Tazewell, Russell, Scott, and Albemarle. Of this number, only one county, Wythe, has shown as yet producing mines. More or less prospecting has been attempted in the majority of the counties named above, and small amounts of the ore have been mined in a number of them.

Geologically, the occurrence of lead and zinc ores in southwest Virginia is limited to the magnesian limestone of Cambro-Ordovician age, known as the Shenandoah or Valley limestone. The known commercial deposits of these ores occur near the eastern side of the Valley, though several promising prospects are opened near the western side.

The ores include (1) the original sulphide forms sphalerite (sulphide of zinc), galenite (sulphide of lead), pyrite (sulphide of iron), and in several places chalcopyrite (the double sulphide of iron and copper); and (2) the secondary or oxidized forms which have been derived from the original sulphides and occur in the residual clays derived by weathering from the limestone. These include calamine (hydrous silicate of zinc), smithsonite (carbonate of zinc), and cerussite (carbonate of lead). Named in the order of their importance, dolomite, calcite, barite, fluorite, and quartz are the associated non-metallic minerals.

The bulk of the sulphide ores belong to the disseminated replacement breccia type. Little or no replacement of the limestone by the ore is indicated in some places. The zones of breccia ore are associated with faulting and folding. Not all parts of the breccia zones are mineralized, but the ore is distributed at irregular intervals. The oxidized ores usually show much richness, and are often concentrated in massive form as large, irregular masses and layers, principally at and near the bottom of the residual clays, closely hugging the irregular weathered surface of the limestone. Until recently only the oxidized or secondary ores have been mined. These have been practically exhausted and attention is now directed to mining the original sulphide ores in the fresh limestone.

The ores are shipped to Pulaski, and smelted at the zinc smelting plant of the Bertha Mineral Company. Three grades of spelter are made, branded according to purity: "Bertha Pure Spelter," "Old Dominion," and "Southern."

The single deposit of lead and zinc ores in Albemarle County is the only type of its kind known in the South. The mine is owned by the Albemarle Zinc and Lead Company, and is located two miles slightly north of east from Faber. The associated rocks are metamorphic crystalline schists, cut by dikes of diorite and diabase. The metalliferous vein, traced for a distance of several miles, averages about four feet in width, strikes N. 45° E., and dips 80° to 85° northwest. Where opened, the vein is of the lenticular type, composed of bulbous bodies of fluorspar and some quartz through which the ore, blende and

galena, is distributed. The ore is treated in an 80-ton mill erected at the mine.

The production of lead in Virginia in 1908 was 76,190 pounds, valued at \$3,200. There was no production of lead or zinc reported from the Virginia mines in 1909. The production of zinc reported is to be credited to the reworking of old dumps. The 1910 production of lead amounted to 198,850 pounds, valued at \$8,750.

The production of spelter in Virginia in 1906 was 1,143 short tons, valued at \$139,446; in 1907, 771 short tons, valued at \$90,978; in 1908, 910 short tons, valued at \$85,540; in 1909, 58 short tons, valued at \$6,298; and in 1910, 794+ short tons, valued at \$85,758.

TIN.

Though not a producer of tin, the existence of tin ore in the Irish Creek area of Rockbridge County has been known for many years, and in 1883 and later the deposits were opened in several places. The Irish Creek area is about 4 miles long in a northeast-southwest direction and 3 miles wide, embracing a total area of 12 square miles. The immediate rocks of the area are of granitic composition, composed principally of a coarse aggregate of quartz and feldspar (orthoclase and albite), with hornblende, and in places some epidote. Dikes of fine-grained altered diabase cut the granitic rocks in all directions, and apparently are frequently associated with the tin-bearing veins.

The tin ore (cassiterite) occurs principally in greisen veins, which traverse the granite in all directions and have steep though varying dips. The veins are usually narrow, not exceeding a foot and less, though a greater thickness is frequent and some of the veins measure several feet across. The cassiterite is disseminated in small crystals and fine grains indistinguishable to the naked eye. The associated minerals comprise wolframite, mispickel (arsenopyrite), pyrite, and beryl. In addition to these, siderite, limonite, chlorite, muscovite, damourite, and fluorspar have been reported. The mispickel is reported by McCreath to contain both gold and silver.

NICKEL AND COBALT.

The existence of nickel in Virginia has been reported from a number of localities in the Piedmont region, especially in association with the extensive pyrrhotite bodies of the Floyd-Carroll-Grayson counties plateau in southwest Virginia, and in Amherst County east of Lynchburg. More recently nickel in association with peridotite masses has been reported from near Broadrun station in Fauquier County. In addition to the above occurrences, cobalt is found in association with some of the impure earthy manganese deposits of the Valley region, especially along the western base of the Blue Ridge.

Probably the most encouraging locality in the State from which nickel has been reported is in the northern part of Floyd County, where considerable exploratory work on Flat Run and Lick Fork has been carried on. The Lick Fork openings are the principal ones in the area, and the ore is chiefly pyrrhotite with some chalcopyrite. At the time of my visit in May, 1907, a large amount of ore on the dump was reported to average by actual assays not less than 1.75 per cent of nickel and a fraction of 1 per cent of copper. As much as 0.4 per cent of cobalt was reported, but the average is considerably less. Assays of the pyrite from other openings in the area are reported to yield from 3 to 4 per cent of nickel.

The rocks immediately associated with the ore are, without exception, of igneous origin, and comprise pyroxene syenite, diabase, and gabbro. These are intruded into the country schists and gneisses. The gabbro and diabase penetrate the pyroxene syenite in dike-like forms and are accordingly younger in age. The mica-gabbro is the ore-bearing rock. In some parts of the gabbro, the sulphides are sparingly present, in others they make up 50 per cent and more of the total rock mass, with all gradations between.

COAL.

The first coal mined in the United States was in the Richmond basin, where mines were opened and worked on the James River, near Richmond, as early as 1750. The production from the Richmond basin increased until 1832 (the production in 1828 being 100,280 tons), when it began to decline. In 1908, redevelopment of the mines at

Gayton by the Old Dominion Development Company was begun, and in 1910 a good production was reported by the company.

The construction of the Norfolk and Western Railway through southwest Virginia in 1882, opened up the famous Pocahontas coal district, which lies partly in Virginia. Likewise, the building of the Clinch Valley division of the Norfolk and Western Railway, nine years later, marked the beginning of the development of the Wise County coal district. The developments in these two fields in southwest Virginia, Tazewell County in 1883 and Wise County in 1891, restored Virginia to importance as a coal producer.

Coal was mined in the Montgomery-Pulaski counties area prior to the Civil War, but not in an extensive way. For a period of 30 years after the Civil War, the only mining carried on in this field was to supply a limited local market. Within recent years larger developments have been made, and until the beginning of the financial panic in the latter part of 1907, the production was correspondingly increased.

Coal is mined in two of the three major provinces of the State, namely, the Mountain province and the Piedmont province. Recent developments in the Piedmont province (Richmond coal basin) will undoubtedly restore this area again to the rank of an important producer.

The Virginia areas which have produced or are producing coal are as follows:

- I. The coal deposits of the Piedmont province. Includes the Richmond Coal Basin, which covers parts of the following five counties: Henrico, Chesterfield, Powhatan, Goochland, and Amelia. This is the only area of free-burning coal in the eastern portion of the United States that is located immediately adjacent to tidewater. The Farmville area, which covers parts of Prince Edward, Cumberland, and Buckingham counties.
- II. The coal deposits of the Mountain province, which include a number of separate areas extending across the State in a southwesterly direction from Frederick County on the north to the Tennessee boundary on the south.
 - (1) The Frederick County Area. Including the Mountain Falls district in the southwestern portion of the county and near the West Virginia line.
 - (2) The Augusta County Area. Includes the North River district in the northwest corner of Augusta County and the contiguous part of Rockingham County.

- (3) The Botetourt County Area. Includes the southwest corner of Botetourt County.
- (4) The Montgomery-Pulaski Counties Area. Includes Price and Brush mountains in Montgomery County, and Cloyd and Little Walker mountains in Pulaski County.
- (5) The Bland-Wythe Counties Area. Includes a small area in the southern part of Bland County and in the northern part of Wythe County.
- (6) The Southwest Virginia Area. Forms the southeastern portion of the Kanawha basin, and comprises the Pocahontas or Flat-Top and the Big Stone Gap coal fields of the following counties: Tazewell, Russell, Scott, Buchanan, Wise, and Lee.

Geologically, the Virginia coal deposits are grouped as (1) those of Triassic age, including the Richmond coal basin, and (2) those of Carboniferous age, which includes all coal deposits found west of the Blue Ridge. Of the Carboniferous coal deposits, those of the Mountain Falls district, in Frederick County, the North River area of Augusta County, the North Mountain area of Botetourt County, the Montgomery-Pulaski counties area, and the Bland-Wythe counties area are Mississippian (Lower Carboniferous) in age. The Virginia portion of the Appalachian coal field, which includes the extreme southwest counties along the border of West Virginia and Kentucky, and to which the State owes its rank as a coal producer, is Pennsylvanian (Upper Carboniferous) in age.

The southwest Virginia coal field forms the southwestern part of the Kanawha basin and comprises the following counties: Buchanan, Dickenson, Lee, Russell, Scott, Tazewell, and Wise. Of these, Wise, Tazewell, and Lee counties are the most important producers at present. The other counties contain large reserves of coal, which in places are rapidly undergoing development. This is especially true of Russell County, whose coal production increased more than 100 per cent in 1909. Many of these reserves have been made accessible recently through the construction of new lines of railroad, which means increased activity in coal mining in the State and a greater production in the immediate future.

It is due to the southwest Virginia fields that Virginia is entitled to rank among the principal coal-producing states. This area, the Virginia portion of the Appalachian coal field, is estimated to contain

1,550 square miles, with the original supply of coal placed at 22,500,000,000 short tons. Campbell and Parker state that from this there had been produced, at the close of 1907, a total of 57,229,152 short tons, representing an exhaustion of 86,000,000 tons. "The production in 1907 was 4,710,895 short tons, equivalent to an exhaustion of little over 7,000,000 tons, so that the coal left in the ground in Virginia at the close of 1907 was 2,000 times the exhaustion represented by the production of that year."

The Pocahontas and Big Stone Gap coal fields are the most extensively developed coal fields in the Virginia portion of the Appalachian region.

A goodly number of coal beds are found within the total vertical limits of the geological formations composing the Pocahontas field. Some of these are thin, but at least six workable beds have been opened in places. Not all of these are workable, however, at any one locality, and in places only one is worked. The superior quality of the Pocahontas coal has long established it as the best steam coal in the world. It produces an excellent coke, but, as a rule, the lump coal is placed directly upon the market for general purposes, while the slack and fine coal go direct to the ovens for coking.

The Big Stone Gap coal field in Virginia embraces parts of Lee, Scott, and Wise counties. Although opened up nearly ten years after the famous Pocahontas field, it is much the largest producer of coal and coke, and Wise County is the largest coal- and coke-producing county in the State. Wise County contributes at present about 60 per cent of the State's total coal production.

There are eight workable seams of coal in the district, ranging in thickness from 3.5 to 12 feet, included within a vertical distance of about 1,200 feet. Of these, the four highest have their greatest development in the western part of the district.

The coal mining industry in Virginia showed a marked increase during the years 1909 and 1910 over that of previous years. Virginia was one of the few states whose production in 1909 exceeded that of 1907, which was due to the increased production in Wise County and to active development in Russell County. The production in Wise County increased from 2,558,874 short tons in 1908 to 2,841,448 tons

in 1909. Russell County's production increased more than 100 per cent. The production in Tazewell County was 4,349 tons less in 1909 than in 1908, and in Lee County 15,117 tons less in 1909. The total production in Virginia for 1909 amounted to 4,752,217 short tons, valued at \$4,251,056, as compared with 4,259,042 short tons, valued at \$3,868,524, in 1908. This represents an increase in quantity of 493,175 short tons, or 11.5 per cent, and in value of \$382,502. The average price per ton was 89 cents in 1909 against 91 cents in 1908 and \$1.02 in 1907. The number of mining machines increased from 85 in 1908 to 107 in 1909, and the machine-mined coal increased from 1,035,832 tons to 1,323,111 tons, nearly 30 per cent of the total quantity of coal mined in 1909. None of the Virginia coal is washed before being sold or used.

Virginia established a new record in her coal production in 1910. The production in Lee, Russell, Tazewell, and Wise counties showed a marked increase in 1910 over that of the previous year, due to the considerable development in progress, not so much in the way of new companies, but in the expansion of properties already developed. This is particularly true of Russell County. The reason for the increased production in 1910 over that of 1909 was indirectly the strike in the coal mines of Illinois and the southwestern States.

The production in Tazewell County increased from 975,665 short tons in 1909 to 1,187,146 short tons in 1910; in Wise County from 2,841,448 short tons in 1909 to 3,730,992 short tons in 1910; and in Lee County from 485,960 short tons in 1909 to 792,763 short tons in 1910. The total production of coal in Virginia during 1910 amounted to 6,507,997 short tons, valued at \$5,877,486, representing an increase over the 1909 production of 1,755,780 short tons in quantity, and \$1,626,430 in value. This is the largest tonnage of coal ever produced in Virginia during a single year. The average price per ton of coal in the State during 1910 was 90 cents as against 89 cents in 1909. The number of mining machines increased from 107 in 1909 to 142 in 1910, and the machine-mined coal increased from 1,323,111 short tons to 2,290,435 short tons, more than 35 per cent of the total quantity of coal mined in 1909.

The accompanying table gives the quantity and value of coal produced in Virginia from 1890 to 1910, inclusive.

Quantity and value of Coal produced in Virginia, 1890 to 1910, inclusive.

Year	Quantity (short tons)	Value
1890.....	784,011	
1891.....	736,399	
1892.....	675,205	
1893.....	820,339	
1894.....	1,299,083	
1895.....	1,368,324	
1896.....	1,254,723	\$ 848,851
1897.....	1,528,302	1,021,918
1898.....	1,815,274	1,070,417
1899.....	2,105,791	1,304,241
1900.....	2,393,754	2,123,222
1901.....	2,725,873	2,353,989
1902.....	3,182,993	2,543,595
1903.....	3,451,307	3,302,149
1904.....	3,583,914	3,076,011
1905.....	4,275,271	3,777,325
1906.....	4,254,879	4,183,991
1907.....	4,710,895	4,807,533
1908.....	4,259,042	3,868,524
1909.....	4,752,217	4,251,056
1910.....	6,507,997	5,877,486

There is given in the table below the production of coal in Virginia from 1900 to 1910, by counties.

Coal Production of Virginia, 1900-1910, by counties, in short tons.

County	1900	1901	1902	1903	1904
Montgomery	9,814	11,177	12,786	20,288	.....
Tazewell	970,866	776,568	723,753	840,195	871,720
Wise	1,363,570	1,918,693	2,422,417	2,563,285	2,359,661
Chesterfield }				18,084	2,100
Henrico }	49,504	19,435	24,037 ^a		
Pulaski }				9,255	177,133 ^b
Russell					
Lee					
Small mines				200	300
Total	2,393,754	2,725,873	3,182,993	3,451,307	3,410,914
Total value.....	\$2,123,222	\$2,353,989	\$2,543,595	\$3,302,149	\$3,302,149

Coal Production of Virginia, 1900-1910, by counties, in short tons.—
Continued.

1905	1906	1907	1908	1909	1910
.....	.....	.....	6,022	(d)	(d)
961,380	910,638	1,116,534	980,014	975,665	1,187,146
2,990,698	3,041,225	3,145,846	2,558,874	2,841,448	3,730,992
.....					
323,073 ^c	302,896 ^c	448,515 ^c	249,671	(d)	(d)
.....	.....	.....	.....	(d)	(d)
.....	.....	.....	464,261	449,144	797,096
120	.....	.....	200	485,960 ^e	792,763 ^f
.....					
4,275,271	4,254,879	4,710,895	4,259,042	4,752,217	6,507,997
\$3,777,325	\$4,183,991	\$4,807,533	\$3,868,524	\$4,251,056	\$5,877,486

^aIncludes Chesterfield and Pulaski counties.

^bIncludes Montgomery County.

^cIncludes Lee and Montgomery counties.

^dIncluded under "Small mines."

^eIncludes Montgomery, Pulaski, and Russell counties.

^fIncludes Montgomery, Henrico, Pulaski, and Russell counties.

LIST OF COAL OPERATORS

OPERATOR	OFFICE	MINE
American-Pocahontas Coal Co.....	Washington, D. C.....	American-Pocahontas
Barrowman Coal Co.....	Banner	Spruce Pine
Beacham Coal Co.....	Christiansburg	Beacham
Belle Hampton Coal Mining Co.....	Binghampton, N. Y....	Belle Hampton
Big Vein Pocahontas Coal Co.....	Baltimore, Md	Big Vein Nos. 1 & 2
Black Mountain Collieries Co., Inc.....	Pennington Gap	Black Mountain No. 1
Black Mountain Mining Co.....	Big Stone Gap.....	Black Mountain
Blackwood Coal & Coke Co.....	Blackwood	Blackwood and Roaring Fork
Bond Coal Co.....	Tacoma	Greeno
Bondurant Coal & Coke Co.....	Pennington Gap	Bondurant
Browning, James S.....	Pocahontas	Browning
Bruce Coal & Coke Co.....	Tacoma	Bruce
Buchanan Coal & Coke Co.....	Richmond	Prospect
Catawba Mining & Mfg. Co.....	Roanoke	
Chesterfield Coal Co.....	Winterpock	Clover Hill
Clinchfield Coal Corporation.....	Dante and Johnson City, Tenn.	Cranes Nest
Clinch River Coal Co.....	Richlands	Clinch River
Clinch Valley Lumber Co.....	St. Paul	
Colonial Coal & Coke Co.....	Dorchester	Dorchester
Darby Coal & Coke Co.....	Cincinnati, Ohio	Darby
Dickenson, W. E.....	Coeburn	
Dixie Coal & Coke Co.....	Raven	Dixie
Domestic Coal Co.....	Raven	Domestic
Dominion Coal Co.....	Pennington Gap	Blanche, Early, Mabel Edgar, and Susie Ferge
Empire Coal Land Corporation.....	Alfredton	Seaboard
Esser Coal & Coke Co.....	Esserville	Esserville

OPERATOR	OFFICE	MINE
Fleming & Co., Robert.....	Norton	Banner
Goodloe Bros. Co., Inc.....	Big Stone Gap.....	Pin Hook
Hale, J. E.....	Wise	
Huettel Coal & Coke Co.....	Norton	Huettel
Hyndman Coal & Coke Co.....	Norton	Carlson
Imboden Coal & Coke Co.....	Imboden	Imboden
Intermont Coal & Iron Co. (Kelly & Irvine).....	Big Stone Gap.....	Josephine
James River Coal Corporation.....	Midlothian	Midlothian
Jewell Ridge Coal Co.....	Tazewell	Jewell Ridge
Keokee Consolidated Coke Co.....	New York, N. Y.....	Imboden, Keokee
Kinzer & Son.....	Vicar Switch	Stroubles Creek
Lee Coal Co.....	Middlesboro, Ky.....	Lee
Lick Branch Anthracite Coal Co.....	Christiansburg	
Litz, J. L.....	Coeburn	
Monarch Coal Co., Inc.....	Cincinnati, Ohio	Leona
Norton Coal Co.....	Norton	Norton, Nos. 1, 2, and 3
Old Dominion Development Co.....	Richmond	Carbon Hill
Pennington Coal Co., Inc.....	Pennington Gap	Pennington
Pocahontas Consolidated Collieries Co.....	Pocahontas	Boissevain and Pocahontas
Pocahontas Mining Corporation.....	Tazewell	Big Creek
Pound River Coal Corporation.....	Wise	Pound River
Price Bros	Cambria	Blacksburg Mng. & Mfg. Co.
Price Mountain Coal Co. (Bandy, Warren & Hawser).....	Roanoke	Myers
Pulaski Anthracite Coal Co.....	New York, N. Y.....	Parrott
Raven Collieries Co.....	Raven	Coal Creek
Raven Fuel Co.....	Raven	Red Ash
Raven Red Ash Coal Co.....	Red Ash	Red Ash
Richlands Coal Co.....	Richlands	Richlands
St. Paul Coal & Coke Co.....	St. Paul	St. Paul
Scott County Mineral Co.....	Bristol, Tenn	
Slusser & Co., M. C.....	Blacksburg	Brush Mountain
Smith & Co., H. P.....	Blacksburg	Snider Hill
Southern Anthracite Coal Co.....	Roanoke	Clear Air
Southern Pocahontas Coal Co.....	Richlands	Sater
Stonega Coke & Coal Co.....	Big Stone Gap	Arno, Nos. 1 and 2; Crossbrook, Osaka; Roda, and Stonega
Stonegap Colliery Co.....	Glamorgan	Glamorgan
Sutherland Coal & Coke Co.....	Dorchester	Sutherland
Tacoma Coal & Coke Co.....	Tacoma	Tacoma
Town Hill Coal Co., W. R. Williams.....	Bramwell, W. Va.....	Town Hill
Trigg & Kent.....	Bristol, Tenn	T. & K.
Virginia Anthracite Coal Co.....	Richmond	Merrimac
Virginia City Collieries Co.....	Virginia City	Virginia City
Virginia Iron, Coal & Coke Co.....	Roanoke	Coeburn, Inman, Lee, Linden, Looney Creek, Marion, Pine Run, Swansea, Sexton, and Thelma
Virginia Lee Co., Inc.....	Pennington Gap	St. Charles and Virginia Lee
Virginia-Tennessee Coal Co.....	Knoxville, Tenn	Coal Creek
Wise Coal & Coke Co.....	Dorchester	Wise
Yellow Creek Coal & Coke Co., Inc.....	Wise	Yellow Creek

COKE.

The coking coals of Virginia are confined to a few counties in the extreme southwestern portion of the State. The rapid development of the coking-coal fields in this portion of the State during the last few years has given Virginia rank as one of the four principal coke-producing states. Prior to 1895, there were only two coke-making establishments in Virginia, with a production of less than 200,000 tons per year. The number of establishments increased to seven in 1901, and the total number of coke ovens increased from 832 in 1896, to 2,775 in 1901, with a total production of more than 900,000 short tons. Construction and development work progressed rapidly during 1902, the number of establishments was doubled, and, at the close of the year, 2,974 ovens were built and 1,208 were building, with the production increased 1,124,572 short tons.

In 1903, two more establishments were added, making the total number 16, with a total of 4,251 ovens, and the production further increased to 1,176,439 short tons. In 1904, there was an increase of 94 completed ovens, the number of establishments remaining the same as in 1903, while the production declined to 1,101,716 short tons. Two establishments having a total of 107 ovens were reported idle during the year 1904. One of these was the Newton-Chambers ovens at Pocahontas in Tazewell County.

The production of coke in 1905 amounted to 1,499,481 short tons, valued at \$2,869,452, as compared with 1,101,716 short tons, valued at \$1,772,717 in 1904, an increase of 36.1 per cent in quantity, and 62 per cent in value. The number of ovens increased from 4,345 in 1904 to 4,549 in 1905, an increase of 204.

There were 18 establishments in 1906, an increase of two over 1905, and the total number of ovens increased from 4,549 to 4,641 in 1906. The production increased from 1,499,481 short tons in 1905, valued at \$2,869,452, to 1,577,659 short tons, valued at \$3,611,659. The value of coke at the ovens increased from \$1.91 per ton to \$2.29.

In 1907, the production of coke decreased from 1,577,659 short tons in 1906, to 1,545,280, a loss of 32,379 tons, or 2.1 per cent. Owing, however, to better prices which prevailed in 1907, the value of the coke produced increased from \$3,611,659 in 1906 to \$3,765,733

in 1907, an increase of \$154,074, or 4.3 per cent. There were 19 establishments in 1907, an increase of one over 1906, and the number of ovens increased from 4,641 to 5,333 in 1907.

The monetary troubles in the latter part of 1907 very seriously effected the coke industry in the State during 1908. There was a decrease in the amount of coke from 1,545,280 short tons in 1907 to 1,162,051 tons in 1908, a loss of 383,229 tons, or 24.8 per cent; and, in value, a decrease from \$3,765,733 in 1907 to \$2,121,980 in 1908, a loss of \$1,643,753, or 43.65 per cent. The value of coke at the ovens decreased from \$2.44 per ton in 1907 to \$1.83 in 1908. The number of establishments (19) remained the same as for 1907, but there was a decrease in ovens from 5,333 to 4,853 in 1908.

The production of coke in Virginia during 1909 was 1,347,478 short tons, valued at \$2,415,769, which represented an increase over the production for the previous year, of 185,427 tons in quantity and \$293,789 in value. The number of ovens reported in existence was 5,469; number building, 100. The value of coke per ton was \$1.79 as compared with \$1.83, the value per ton in 1908.

The production of coke in Virginia during 1910 was 1,493,655 short tons, valued at \$2,731,348, which represented an increase over the production for 1909 of 146,177 tons, or 10.9 per cent, and \$315,579, or 13.1 per cent, in value. The number of establishments was reduced from 19 to 18 and the number of ovens from 5,469 to 5,389. There were 100 beehive ovens in course of construction at the close of 1910. The value of coke per ton increased from \$1.79 in 1909 to \$1.83 in 1910.

The principal part of the coke production in Virginia during the last few years has been from the development of the coal fields in Wise County, on the Clinch Valley division of the Norfolk and Western Railway. During 1906 and 1907 extensive developments were made in the Black Mountain field in Lee County following the construction of the Black Mountain railroad. The first ovens in Lee County were reported under construction in 1907, with an output in 1908 of 50,000 tons, which was increased to over 100,000 tons in 1909, but decreased to 86,000 tons in 1910. The production in other districts increased during 1910, and the total output for the State showed an

increase of 146,177 tons, or 10.9 per cent, and in value of \$315,579, or 13.1 per cent. The average price per ton advanced from \$1.79 in 1909 to \$1.83 in 1910. The coal for the plant at Lowmoor and the one at Covington is drawn from the mines in the New River district of West Virginia, and that for the ovens at Pocahontas in Tazewell County is obtained from mines extending across the State boundary into West Virginia.

Of the 1910 production of coke in Virginia, 1,025,144 short tons of the total tonnage (1,493,655) came from Wise County. The value of the production from Wise County was \$1,883,344. In order to avoid disclosing individual figures, it is not possible to publish the production of the other counties producing in 1910. These counties, however, listed in order of productions were: Roanoke, Tazewell, and Alleghany.

In the subjoined table are shown the statistics of the manufacture of coke in Virginia in 1883, when the first operations were begun, in 1890, 1900, and from 1903 to 1910, inclusive.

Statistics of the manufacture of Coke in Virginia, 1883-1910.

Year	Estab- lish- ments	Ovens		Coal used (short tons)	Coke produced (short tons)	Total value of coke at ovens
		Built	Building			
1883	1	200	0	39,000	25,340	\$ 44,345
1890	2	550	250	251,683	165,847	278,724
1900	7	a2,331	300	1,083,827	685,156	1,464,556
1903	16	a4,251	142	1,860,225	1,176,439	2,724,047
1904	16	a4,345	68	1,636,905	1,101,716	1,772,717
1905	16	a4,549	0	2,184,369	1,499,481	2,869,452
1906	18	a4,641	695	2,296,227	1,577,659	3,611,659
1907	19	a5,333	50	2,264,720	1,545,280	3,765,733
1908	19	4,853	158	1,785,281	1,162,051	2,121,980
1909	19	5,469	100	2,060,518	1,347,478	2,415,769
1910	18	a5,389	100	2,310,742	1,493,655	2,731,348

aIncludes 56 Newton-Chambers by-products ovens.

All the coal used in coke-making in Virginia up to 1895 was unwashed. Washing of slack coal began in 1896, and in 1898 the amount of washed slack coal used amounted to 210,000 short tons. All the coal

used in the manufacture of coke in the State during the years 1909 and 1910 was unwashed. Of the 2,310,742 short tons of coal made into coke during 1910, 1,554,784 tons were run-of-mine and 755,958 tons were slack.

The character of the coal used in coke-making in Virginia during 1890, 1900, and from 1903 to 1910, inclusive, is shown in the table below.

*Character of Coal used in the manufacture of Coke in Virginia,
1890-1910, in short tons.*

Year	Run-of-Mine		Slack		Total
	Unwashed	Washed	Unwashed	Washed	
1890	98,215	0	153,468	0	251,683
1900	620,207	0	463,620	0	1,083,827
1903	857,332	0	1,002,893	0	1,860,225
1904	1,213,226	44,222	379,457	0	1,636,905
1905	1,096,656	0	1,087,713	0	2,184,369
1906	1,014,299	228,347	1,053,581	0	2,296,227
1907	1,271,518	0	993,202	0	2,264,720
1908	1,438,754	0	346,527	0	1,785,281
1909	1,405,111	0	655,407	0	2,060,518
1910	1,554,784	0	755,958	0	2,310,742

LIST OF COKE OPERATORS

OPERATOR	OFFICE	MINE
Blackwood Coal & Coke Co.....	Blackwood	Blackwood
Colonial Coal & Coke Co.....	Dorchester	Dorchester
Empire Coal Land Corporation.....	Alfredton	Alfredton
Esser Coal & Coke Co.....	Esserville	Norton
Hyndman Coal & Coke Co.....	Norton	Hyndman
Imboden Coal & Coke Co.....	Imboden	Imboden
Intermont Coal & Iron Co.....	Big Stone Gap.....	Near Norton
Keokee Consolidated Coke Co.....	New York, N. Y.....	Imboden and Keokee
Lowmoor Iron Co. of Virginia.....	Lowmoor	Covington and Lowmoor
Norton Coal Co.....	Norton	Norton
Pocahontas Consolidated Collieries Co.....	Pocahontas	Pocahontas
Stonega Coke & Coal Co.....	Stonega, Osaka, and Imboden, Osaka, and Philadelphia, Pa.	Stonega
Stonegap Colliery Co.....	Glamorgan	Glamorgan
Sutherland Coal & Coke Co.....	Dorchester	Manning
Virginia Iron, Coal & Coke Co.....	Roanoke	Toms Creek and Inman
Wise Coal & Coke Co.....	Dorchester	Dorchester

CLAYS AND CLAY PRODUCTS.

Virginia contains a variety of clays widely distributed and occurring at various geological horizons. They are found abundantly distributed throughout the Coastal Plain, Crystalline, and Mountain provinces of the State, and are adapted to a wide range of uses. Many of the deposits remain undeveloped, because they have not yet been investigated, and little is known regarding them. The only ones which have been systematically studied are those of the Coastal Plain or Tidewater region.

The clays of Virginia are suitable for many economic purposes, and can be divided into two groups, namely, residual and sedimentary. The residual clays have been formed by the weathering of rocks, involving processes of disintegration and decomposition. As a result of this, we find the residual clays overlying the parent rocks from which they were derived, forming deposits of variable thickness, depending partly on the depth to which the rocks have been changed, and partly on the amount of erosion they have suffered since their formation. Residual clays predominate in the belt (Piedmont region) underlain by the crystalline rocks, such as granites, gneisses, schists, etc., and have wide distribution west of the Blue Ridge. They are usually quite ferruginous and, therefore, red-burning. Their main use is for the manufacture of brick and drain tile, and some of the smoother deposits have been employed for making smoking pipes, notably those of Powhatan County.

The decomposition of pegmatite dikes in many of the Piedmont counties has yielded clays of high grade, free from iron, and sometimes sufficiently white to be used for the manufacture of white-ware products. Deposits of this type, known as kaolin, have been found in Amherst, Campbell, Hanover, Henry, Mecklenburg, Nelson, Patrick, and other counties in the Piedmont region.

The sedimentary clays represent deposits which have been laid down under water, one layer on another, the materials composing them consisting of the products of rock decay, which have been removed by erosion from the land surface, and washed down into the lakes or seas, where they have finally settled. These are abundant in both the

Coastal Plain province, where they are usually of unconsolidated character, and west of the Blue Ridge, in which region they are largely of a hard and shaly nature. They have wide distribution both geologically and geographically.

The Coastal Plain clays that have proved to be of marked value to the clay worker, occur in Eocene and Miocene beds of the Tertiary, and the Pleistocene of the Quaternary. The Eocene clays are best developed in the region south of Stafford Courthouse, where they form promising outcrops, but have not yet been developed. The Miocene clays are best known south of Richmond, in the vicinity of Curle's Neck, and Bermuda Hundred. This same formation also carries extensive beds of diatomaceous earth or clay, which is well exposed at Richmond and along the Rappahannock River. The Pleistocene clays occur as more or less basin-shaped deposits, widely scattered over the Coastal Plain region, and rest on top of the other formations.

Nearly all of the clay deposits noted in the Coastal Plain region, whatever their geological age, are of lenticular or lens-shaped character. The majority of them are red-burning, while only a few are buff-burning. No white-burning clays have thus far been found; but even though they lack in variety, so far as their color-burning qualities are concerned, it is probable that their possible uses are more numerous than is now supposed. Physical tests and chemical analyses of the clays in Tidewater Virginia are given in Bulletin I-A of the Virginia Geological Survey.

West of the Blue Ridge, in the Mountain province, shales probably suitable for brick-making have wide distribution, ranging in age from Cambro-Ordovician to Carboniferous. Many of these shale deposits will doubtless prove available for the manufacture of vitrified brick.

The abundant deposits of Virginia clays are only partially utilized at present, but, after their thorough investigation by the State Geological Survey and their uses better made known, they will be much more extensively employed and the industry greatly enlarged or expanded.

In 1909, the total value of all clay products manufactured in Virginia, including the value of kaolin, pottery products, fire clay, and miscellaneous clay mined and sold in the State, amounted to

\$1,957,367. Compared with the value (\$1,540,157) of the 1908 production, there was an increase of \$417,210 or nearly 27 per cent.

In 1910, the total value of all clay products manufactured in Virginia was \$1,841,731, a decrease from that of 1909 of \$115,636.

The following table gives the statistics of clay products in Virginia from 1905 to 1910, inclusive, and is of interest to those who desire to know something of the growth of the industry in the State. The item "Miscellaneous" in the table includes all products not otherwise specified (fire brick, sewer pipe, drain tile, fancy or ornamental brick, kaolin, and pottery products), and those which could not be published separately without disclosing individual returns.

Clay Products in Virginia from 1905 to 1910, inclusive.

Product	1905	1906	1907
Brick:			
Common—			
Quantity	237,161,000	232,697,000	197,052,000
Value	\$1,572,442.00	\$1,536,312.00	\$1,285,374.00
Average per thousand.....	\$6.63	\$6.60	\$6.52
Vitrified—			
Quantity	(a)		
Value	(a)		
Average per thousand.....	\$10.00		
Front—			
Quantity	22,155,000	25,385,000	19,989,000
Value	\$352,297.00	\$392,130.00	\$290,411.00
Average per thousand.....	\$15.90	\$15.45	\$14.53
Fancy or ornamental. Value.....	\$20,363.00	(a)	(a)
Fire. Value	(a)	\$21,110.00	(a)
Drain tile. Value.....	\$4,500.00	\$4,805.00	\$6,250.00
Sewer pipe. Value			
Pottery:			
Earthenware and stoneware. Value..			
Porcelain electrical supplies. Value..	(b)	(b)	(b)
Miscellaneous. Value	\$44,976.00	\$11,721.00	\$29,300.00
Total value	\$1,994,578.00	\$1,966,078.00	\$1,611,335.00
Number of operating firms reporting..	94	91	87

aIncluded in miscellaneous.

bThe value of pottery products for Virginia from 1905 to 1910, inclusive, is included under miscellaneous.

Clay Products in Virginia from 1905 to 1910, inclusive.—Continued.

Product	1908	1909	1910
Brick:			
Common—			
Quantity	185,738,000	249,794,000	229,982,000
Value	\$1,219,946.00	\$1,540,648.00	\$1,460,460.00
Average per thousand.....	\$6.57	\$6.13	\$6.35
Vitrified—			
Quantity			
Value			
Average per thousand.....			
Front—			
Quantity	17,858,000	24,717,000	20,813,000
Value	\$246,623.00	\$333,057.00	\$294,348.00
Average per thousand.....	\$13.81	\$13.48	\$14.14
Fancy or ornamental. Value.....	(a)	(a)	(a)
Fire. Value	(a)	(a)	(a)
Drain tile. Value.....	\$7,100.00	\$6,298.00	\$5,276.00
Sewer pipe. Value		(a)	(a)
Pottery:			
Earthenware and stoneware. Value..			
Porcelain electrical supplies. Value..	(b)	(b)	(b)
Miscellaneous. Value	\$66,488.00	\$77,364.00	\$81,647.00
Total value	\$1,540,157.00	\$1,957,367.00	\$1,841,731.00
Number of operating firms reporting..	82	89	87

aIncluded in miscellaneous.

bThe value of pottery products for Virginia from 1905 to 1910, inclusive, is included under miscellaneous.

BRICK CLAYS.

Clays suitable for the manufacture of common and front brick, particularly the former, are widely distributed throughout the State. In fact, nearly every county in Virginia contains clay suitable for the manufacture of common brick, and, in most cases, the deposits are of such character that common brick of the best quality can be made. The brick-yards can be located usually near railroad transportation, and fuel for burning the brick can be obtained, as a rule, at a minimum price. Virginia clays used in the manufacture of common brick are of two types, residual and sedimentary, discussed on page 50.

The total number of common and front brick manufactured in Virginia in 1909 was 274,511,000, valued at \$1,873,705, as against 203,596,000, valued at \$1,466,569 in 1908, an increase of 70,915,000

in quantity and \$407,136,000 in value. Of the 1909 production, 249,794,000 were common brick, valued at \$1,540,648, and 24,717,000 front brick, valued at \$333,057. The average value per thousand of the 1909 production was: Common brick, \$6.13, front brick, \$13.48.

During 1910, the total number of common and front brick manufactured in Virginia was 250,795,000, valued at \$1,754,808, as against 274,511,000, valued at \$1,873,705 in 1909, a decrease of 23,716,000 in quantity, and \$118,897 in value. Of the 1910 production, 229,982,000 were common brick, valued at \$1,460,460, and 20,813,000 front brick, valued at \$294,348. The average value per thousand of the 1910 production was: Common brick \$6.35, front brick \$14.14.

The total value of fancy or ornamental brick and of fire brick produced in Virginia in 1909 was \$30,984, and in 1910, \$24,186. The quantity and value of the different varieties of brick manufactured in Virginia during 1909 and 1910 are given in the tables below.

In the tables below are given the total number and value of common and front brick manufactured in Virginia in 1909 and 1910, by counties.

Production of Common and Front Brick in Virginia in 1909, by counties.

County	Common Brick		Front Brick	
	Quantity (Thousands)	Value	Quantity (Thousands)	Value
Alexandria	75,874	\$ 462,137	24,265	\$ 327,083
Augusta	1,120	9,600		
Chesterfield	15,790	102,231		
Fairfax	9,125	57,584		
Henrico	31,728	201,600		
Nansemond	16,692	97,718		
Roanoke	15,019	94,687		
Rockingham	2,650	17,500		
Other counties	81,796 ^a	497,591 ^a	452 ^b	5,974 ^b
	249,794	\$1,540,648	24,717	\$333,057

^aIncludes Albemarle, Alleghany, Brunswick, Campbell, Carroll, Charles City, Charlotte, Culpeper, Frederick, Grayson, Greensville, Halifax, Henry, Isle of Wight, King George, Lancaster, Lee, Lunenburg, Montgomery, Norfolk, Nottoway, Orange, Pittsylvania, Prince George, Princess Anne, Rockbridge, Russell, Scott, Shenandoah, Spottsylvania, Sussex, Tazewell, and Warwick.

^bIncludes Halifax, Henrico, and Rockingham.

Production of Common and Front Brick in Virginia in 1910, by counties.

County	Common Brick		Front Brick	
	Quantity (Thousands)	Value	Quantity (Thousands)	Value
Alexandria	65,484	\$ 415,551		
Augusta	925	7,300		
Chesterfield	9,115	60,644		
Fairfax	7,595	60,100		
Henrico	20,763	141,844		
Nansemond	16,771	99,545		
Roanoke }	17,300	104,600		
Rockingham }				
Other counties	92,029 ^a	570,876	20,813 ^b	\$294,348
	229,982	\$1,460,460	20,813	\$294,348

^aIncludes Albemarle, Alleghany, Amherst, Brunswick, Campbell, Caroline, Carroll, Charles City, Charlotte, Culpeper, Frederick, Grayson, Halifax, Henry, Isle of Wight, James City, King George, Lancaster, Montgomery, Norfolk, Nottoway, Orange, Pittsylvania, Princess Anne, Powhatan, Rockbridge, Russell, Scott, Shenandoah, Smyth, Spottsylvania, Sussex, Tazewell, and Warwick.

^bIncludes Alexandria, Halifax, Henrico, James City, Pittsylvania, and Powhatan.

FIRE CLAYS.

Refractory clays are known to occur in many localities of the State, but they have not yet been investigated, and the production is small and variable. It is highly probable that the clayey members, including shales of the Carboniferous system of rocks, occurring west of the Blue Ridge and having the most extensive development in south-west Virginia, will prove of sufficient value for making vitrified wares. The Triassic shales associated with the coals of the Richmond basin have not proved of any value for the manufacture of clay products. Clays of the refractory type occur in a number of the Piedmont counties, and have been worked at several localities in some of these.

The production of fire clay during 1909 and 1910 was small and is included under "Miscellaneous" in the table on page 53.

POTTERY CLAYS.

The pottery industry in Virginia is a small one. The total value of pottery products made in Virginia in 1909 amounted to \$36,746, as against \$37,777 in 1908. This represents a decrease of \$1,031. The value of pottery products made in the State during 1910 is included under "Miscellaneous" in the table on page 53.

KAOLIN.

The production of kaolin in Virginia has been derived almost entirely from the decomposed pegmatite dikes, which intersect the crystalline rocks of the Piedmont region. Deposits of this type have been worked in Amelia, Henry, and Nelson counties, and are known to occur but not developed in many other of the Piedmont counties. Of these, Henry is the principal producing county at present.

The production of kaolin in Virginia is small, and is included under "Other products" in the tables on pages 5 and 6, showing the mineral production in Virginia for the years 1909 and 1910.

LIST OF CLAY OPERATORS

OPERATOR	BRICK AND TILE OFFICE	WORKS
Adams Bros. Co., Inc.	Bristol	Bristol
Adams Bros.-Paynes Co., Lynchburg Brick Works, Props	Lynchburg	Deacon
Alleghany Brick Co., Inc.	Covington	Covington
Altavista Brick Co., Inc. (Formerly Frazier Lbr. Co.)	Altavista	Altavista
Baltimore Brick Co.	Richmond	Rocketts
Barr, E. M.	Winchester	Winchester
Bell Bros	Strasburg	Strasburg
Billhimer, W. H.	Harrisonburg	Harrisonburg
Blackburn & Lohr	Staunton	Staunton
Bolling, Thomas A.	Farmville	Farmville
Booker Brick Co.	Newport News	Morrison
Boston Brick Co.	Houston	Houston and South Boston
Brister, C. M.	Petersburg	Ettricks (near)
Brooks & Son, A. M.	New River	Radford
Bromilaw Brick Co.	Alexandria	Hunting Creek
Buck & Co., Levin T.	Weems	Weems
Burroughs & Mankin, Inc.	Richmond	Manbur
Butler, Geo. W.	Culpeper	Culpeper
Capital Brick & Tile Corporation	Washington, D. C.	Alexandria
Champe, John A.	Lexington	Lexington
Charlottesville Brick Co.	Charlottesville	Charlottesville

OPERATOR	OFFICE	WORKS
Cheatwood & Blunt	Richmond	Brook Road
Clarke & Covington	Culpeper	Elkwood
Clark & Crupper	Washington, D. C.	Arlington
Cole & Son, W. C. (Formerly Galax Brick Co.)	Galax	Galax
Cooley Bros., Smith & Co.	Marion	Marion
Copping, H. B.	Chase City	Chase City
Corlon, W. H.	Manchester	Manchester
Covington Brick Co. (Formerly Isaac Clark)	Covington	Covington
Coyner, J. M.	Basic City	Basic City
Croghan, Daniel	Staunton	Staunton
Croushorn, B. G., Lessee of H. V. Croushorn, Prop.	Weyers Cave	Weyers Cave
Crowell W. H.	Bristol	Bristol
Cuthbert Land & Development Co.	Wiehle	Wiehle
Davis Brick Co., Inc., W. Benjamin.	Richmond	Manchester
Dickinson Fire Brick Co.	Buena Vista	Buena Vista
Eureka Brick Co.	Norfolk	Lynnhaven
Face & Son, E. W.	Norfolk	Norfolk
Fellers Stone Co., Inc.	Roanoke	Roanoke
Fitzgerald, N. A. & T. J.	Danville	Danville
Ford & Wells	Lynchburg	Lynchburg
Franklin Brick Co.	Franklin	Franklin
Frazier, W. R.	Suffolk	Suffolk
Fredericksburg Brick Works.	Fredericksburg	Fredericksburg
Fulton Brick Works.	Richmond	Richmond
Gardner, John W.	Mt. Airy, N. C.	Woodlawn
Gilmore, W. J.	Louisa	Louisa
Grinder, E. M.	Washington, D. C.	Rosslyn
Haden, George P. (Formerly B. D. Linney).	Blackstone	Blackstone
Hambrick, S. G.	Lebanon	Barnett
Harrison Construction Co.	Petersburg	Petersburg
Hatcher & Gaither	Orange	Orange
Hicks Brick Co.	Lawrenceville	Lawrenceville
Hoffman, Geo. E.	Culpeper	Culpeper
Holdaway, R. L. (Formerly W. E. Sutherland)	Major	Bridle Creek
Hoshour & Son, John S.	Woodstock	Woodstock and Front Royal
Hoskins, D. W.	South Boston	South Boston
Huffman & Son, J. S.	Buena Vista	Buena Vista
Hurley, S. R.	Grundy	Grundy
Hydraulic-Press Brick Co.	Washington, D. C.	Waterloo
Johnson, W. C.	Spencer	Johnson's Siding
Jones, W. L.	Williamsburg	James City
Keeler & Son, G. B.	Petersburg	Broadway
Kenbridge Brick Co.	Kenbridge	Kenbridge
Lawrenceville Brick & Tile Co., Inc.	Norfolk	Lawrenceville
Layfield, F. G. (Formerly Oldfield Brick & Tile Co., Inc.)	Oldfield	Oldfield
Lemley & Sons, L. F.	Strasburg	Strasburg
Lunenburg Brick & Tile Co.	Kenbridge	Kenbridge
Mayo & Sons, W. R.	Norfolk	Sturgeon Point
Moistproof Pressed Brick Co.	Norfolk	Norfolk
Montgomery Brick Co.	Christiansburg	Christiansburg

OPERATOR	OFFICE	WORKS
Mulberry Island Brick Co.....	Newport News	Mulberry Island
Musser & Son, W. H.....	Abingdon	Emory
Myers, Jacob S.....	Harrisonburg	Harrisonburg
Nalle, Orville	Elkwood	Elkwood
Nansemond River Brick & Tile Co.....	Norfolk	Reid's Ferry
New Washington Brick Co.....	Washington, D. C.....	Abingdon
Norton Brick Co.....	Norton	Norton
Oyster Point Brick Co.....	Oyster Point	Oyster Point
Patuxent Brick Co.....	Washington, D. C.....	Alexandria
Payne & Spindler.....	Drakes Branch	Drakes Branch
Phillips & Bro., C. H.....	Hampton	Hampton
Pierpont Brick Works.....	Salem	Pierpont Siding
Potomac Brick Co.....	Washington, D. C.....	Addison
Potomac River Clay Works.....	Takoma Park, D. C.....	Alexandria
Potts Estate, E. H.....	Chase City	Chase City
Powers Bros. & Maynard.....	Richmond	Richmond
Powhatan Clay Manufacturing Co.....	Richmond	Clayville
Radford Brick Co.....	Philadelphia, Pa	Tiptop
Rea, B. A. (Formerly Jno. W. Legg).....	Stevensburg	Stevensburg
Ready, W. J.....	Manchester	Manchester and Hen- rico
Redford, N. C.....	Richmond	Manchester
Reynolds, R. C. (Formerly T. G. Layfield).....	Oldfield	Oldfield
Richardson & Son, R. H.....	Hampton	Diascond
Richlands Brick Corporation.....	Norton	Richlands
Roanoke Brick Co. (Adams, Payne & Gleaves, Inc., Prop.).....	Roanoke	Roanoke
Roanoke Clay Manufacturing Co.....	Roanoke	Webster
Rosslyn Brick Co.....	Washington, D. C.....	Rosslyn
Rosslyn Clay Material Co., Inc.....	Rosslyn	Rosslyn
Saint Paul Normal & Industrial School.....	Lawrenceville	Lawrenceville
Seale & Co., C. M.....	Rose Hill	Lennie
Shrum Bros	Dayton	Dayton and Harrison- burg
Southern Brick Co. (Formerly Geo. J. Fletcher)	Fredericksburg	Fredericksburg
Southern Clay Manufacturing Co.....	Chattanooga, Tenn	Chilhowie
Southern State Hospital	Marion	Marion
Southside Brick Co.....	Fredericksburg	Fredericksburg
Standard Brick Co., Reed Bros. & Co., Props	Portsmouth	Suffolk
Staunton Realty Corporation.....	Staunton	Staunton
Stonoga Coke & Coal Co. (Formerly Keo- kee Coal & Coke Co.).....	Keokee	Keokee
Stringfellow, S. P., Recvr., American Hy- gienic Fire Brick-Tile Fireproofing Co., Inc	Richmond	Richmond
Suffolk Clay Co.....	Suffolk	Ladysmith
Sweet Briar Institute.....	Sweet Briar	Sweet Briar
Taliaferro, J. L.....	Richmond	Richmond
Travis, Frank M.....	New London	New London
Turner, Mrs. Agnes L.....	Ferguson's Wharf	Ferguson's Wharf
Turner, W. R.....	Petersburg	Ettrick
Udlike, Eston	Charlottesville	Charlottesville
Udlike & Bro., R. L.....	Charlottesville	Charlottesville
Virginia Brick Co.....	Washington, D. C.....	Arlington
Virginia Brick Co.....	Seven Mile Ford.....	Seven Mile Ford

OPERATOR	OFFICE	WORKS
Virginia Brick Co.....	Suffolk	Suffolk
Virginia Brick Works.....	Richmond	East Fulton
Virginia Clay & Material Co., Inc.....	Farmville or Philadel- phia, Pa	Hawk
Virginia Railway Co. (Formerly Lantry Ballast Co.).....	Norfolk	Pembroke
Vulcan Fire Brick Co.....	Baltimore, Md	Wilmont
Walker Brick Co.....	Washington, D. C....	Arlington
Ward Brick Co.....	Galax	Galax
Ward & Cornett	Elk Creek	Elk Creek
Washington Brick & Terra Cotta Co.....	Washington, D. C....	Riverside Park
Watson Brick Corporation, John T.....	Danville	Danville
Waverly Brick Co., Inc.....	Petersburg	Waverly
West Bros. Brick Co.....	Washington, D. C....	Arlington
West End Brick Co.....	Suffolk	Suffolk
Wetherell, Geo. W.....	Blackstone	Blackstone
Whitfield Bros	Suffolk	Suffolk
Williamson, Chas. E.....	Petersburg	Petersburg
Williamson, Hedgecock & Fontaine, Inc....	Martinsville	Fontaine
Wine, J. W.....	Mt. Sidney	Mt. Sidney
Wood & Futrell.....	Emporia	Emporia
Young, Wm. J.....	Manassas	Manassas
Zirkle, W. H.....	Broadway	Broadway
POTTERY		
Adamant Porcelain Co., Ltd.....	Broadway	Broadway and Harri- sonburg
Akron Smoking Pipe Co.....	Mogadore, Ohio	Pamplin City
Bell Bros	Strasburg	Strasburg
Powhatan Pipe Co.....	Michaux	Michaux
RAW CLAY		
Branch, John P.....	Richmond	City Point
Dickinson Fire Brick Co.....	Buena Vista	Buena Vista
Frazer Paint Co.....	Bedford City	Bedford City
McNicol, John A., Recvr., Blue Ridge Kao- lin Co.....	East Liverpool, Ohio...	Oak Level, R. D. Edge- wood
Powhatan Clay Mfg. Co.....	Richmond	Clayville
Swineford, Howard	Richmond	Bermuda Hundred
Virginia Clay & Material Co.....	Farmville	Hawk
Warrell, N. J. & B. E.....	Sylvatus	Sylvatus

LIME AND CEMENT.

Lime and cement are obtained from limestone, which is described on pages 77 to 82, inclusive. Plants for their manufacture are scattered widely over western Virginia, where raw material, admirably adapted to the manufacture of lime and cement, occurs in great abundance. Plants for the burning of lime are found in most of the counties west of the Blue Ridge, while the manufacture of Portland cement is limited at present to two mills, one in Augusta County, the other at

Norfolk. Mills for the manufacture of natural cement are limited to Rockbridge and Botetourt counties. There was no reported production of natural cement in the State for the years 1909 and 1910.

LIME.

During recent years, lime-making in Virginia has been confined to the counties west of the Blue Ridge, where there are numerous plants engaged in the industry. There occur abundant limestones throughout this region admirably adapted to the making of lime. These range from very pure limestones to those high in magnesia. The former when burned or calcined yield "high limes" or "fat limes," while the latter produce "lean" or magnesian limes. Most of the lime made in Virginia belongs to the first class, and is especially valued by the builders and farmers.

The crystalline limestones of the Piedmont Plateau yield when calcined a good grade of lime. Formerly, numerous small kilns were operated within the limits of this region for the production of lime to supply only immediate local demands. In recent years, however, these have been abandoned, and at present no lime is burned from the Piedmont limestones.

The shell marls of the Coastal Plain region are dug and used locally, in the natural state, as fertilizer on the farming lands. These marls frequently form extensive deposits of considerable purity, and since they occur as loose incoherent material, and usually in a finely comminuted state, they can be easily dug and readily applied in the natural state to the soil.

The total production of lime in Virginia in 1909 was 166,695 short tons, valued at \$635,946, as compared with 107,209 short tons, valued at \$424,374 in 1908. This represents an increase of approximately 55.5 per cent in quantity (59,486 short tons) and 49.8 per cent in value (\$211,572). The average price per ton in 1909 was \$3.81½ as against \$3.95 in 1908. This production was distributed over twelve counties and forty-nine producers. The counties producing lime in 1909 were Augusta, Botetourt, Frederick, Giles, Loudoun, Montgomery, Rockbridge, Rockingham, Russell, Shenandoah, Tazewell, and Warren.

The production of lime in Virginia during 1910 amounted to 141,257 short tons, valued at \$563,567. Compared with the figures for 1909, it will be seen that there was a decrease of 25,438 short tons in quantity and \$72,379 in value. There were forty-eight producers of lime in the State during 1910, and the production was distributed among the following 14 counties: Augusta, Botetourt, Frederick, Giles, Loudoun, Montgomery, Norfolk, Roanoke, Rockbridge, Rockingham, Russell, Shenandoah, Tazewell, and Warren.

There are given in the table below the production and value of lime in Virginia during 1909 and 1910, by counties.

Production and value of Lime in Virginia in 1909 and 1910, by counties.

County	1909		1910	
	Production Short tons	Value	Production Short tons	Value
Augusta	3,035	\$ 10,552	1,671	\$ 5,795
Botetourt	30,521	115,069	25,137	95,012
Frederick	29,668	102,500	28,323	106,258
Montgomery	13,370	69,708	(a)	(a)
Rockingham	4,652	16,258	4,548	16,829
Shenandoah	32,164	131,677	45,798	198,186
Other counties ^a	53,285	190,182	35,780	141,437
Total	166,695	\$635,946	141,257	\$563,567

^aIncludes during 1909, Giles, Loudoun, Rockbridge, Russell, Tazewell, and Warren; and during 1910 those of 1909 and the additional counties, Montgomery, Norfolk, and Roanoke.

In the table below is given the production of lime in Virginia in 1909 and 1910, by uses.

Production of Lime in Virginia, in 1909 and 1910, by uses, in short tons.

	1909		1910	
	Quantity	Value	Quantity	Value
Building lime	89,546	\$361,896	76,361	\$322,529
Hydrated lime	(a)	(a)	.....	.....
Paper mills	(b)	(b)	13,714	45,215
Fertilizer	57,606	205,896	33,766	118,419
Gas works .....	.....	.....	.....	.....
Tanneries	1,176	4,489	1,774	6,013
Chemical works	(b)	(b)	3,264	12,641
Dealers—uses not specified..	8,045	28,068	12,378	58,750
Other purposes	22	115	.....	.....
Miscellaneous ^c	10,300	35,482	.....	.....
Total	166,695	\$635,946	141,257	\$563,567

^aOnly a small quantity of the lime produced in Virginia is hydrated.

^bIncluded under miscellaneous.

^cIncludes gas and chemical works.

LIST OF LIME OPERATORS

OPERATOR	OFFICE	KILN
Alleghany Lime Co., Inc.....	Christiansburg	Houchin Station
Andrews & Co., Inc., T. C.....	Norfolk	Norfolk
Beinkampen Lime Co.....	Radford	Radford
Blankenship, S. M.....	Deerfield	Deerfield
Bristol Lime & Stone Co., Inc.....	Bristol, Va.-Tenn	Benhams
Church, E. W.....	Staunton	Craigsville
Conner, I. N.....	Vaocluse Station	Vaocluse Station
Cooper, I. C.....	Hinton	Hinton
Coverston, Eli and Samuel.....	Pelton	Seven Fountains
Crann, I. N.....	Bridgewater	Mossy Creek
Davis, C. W.....	Blacksburg	Blacksburg
Davison, Louis F.....	Harrisonburg	Harrisonburg
Dillon's Sons, E.....	Indian Rock	Indian Rock
Eagle Rock Lime Co.....	Richmond	Eagle Rock
Eureka Lime Co.....	Vicar Switch	Vicar Switch
Evers, D. L.....	Bridgewater	Mossy Creek
Fellsworth Lime Works.....	Staunton	Staunton
Fox, J. W.....	Ottobine	Ottobine
Grove Lime Co., M. J.....	Limekiln, Md	Stephens City
Haldeman, H. F.....	Churchville	Churchville

OPERATOR	OFFICE	KILN
Harris, J. A.....	Stuarts Draft	Stuarts Draft
Herbaugh, Robert L.....	Zepp	Zepp
Hoag Co., William N.....	Strasburg or New York, Strasburg N. Y.	
Hogshead, Thos. K.....	Sangerville	Sangerville
Hogshead, Charles A.....	Mossy Creek	Mossy Creek
Huggins & Co., H. H.....	Roanoke	Roanoke
Kiracofe, C. S.....	Bridgewater	Bridgewater
Kirk, John Y.....	West Norfolk	West Norfolk
Leesburg Lime Co., Inc.....	Leesburg	Leesburg
Limeton Lime Co.....	Limeton	Limeton
Linville Lime Co.....	Linville	Linville
Luray Lime Co.....	Eura	Luray
McIlwee, C. E.....	Zepp	Zepp
McKimmey, A. G.....	Luckets	Luckets
Michael, J. W.....	Springcreek	Sangerville
Miller, E. X.	Bridgewater	Bridgewater
Moore Lime Co.....	Richmond	Eagle Rock
Natural Bridge Lime Co.....	Glasgow	Sherwood
New River Lime Co.....	Ripplemead	Ripplemead
Oak Ridge Lime Firm.....	Mt. Solon	Mt. Solon
Orndorff, M. M.....	Oranda	Oranda
Oyler, George V.....	Winchester	Winchester
Powhatan Lime Co.....	Strasburg	Strasburg
Pullins, A. C.....	Mount Sidney	Mount Sidney
Rawley, N. B.....	Churchville	Churchville
Riverton Lime Co.....	Riverton	Riverton
Roanoke Stone & Lime Co., Inc.....	Roanoke	Lithia
Rockbridge Lime & Stone Co.....	Lexington	Lexington
Rockdale Lime Co.....	Toms Brook	Toms Brook
Rusmiselle, J. A.....	Mt. Solon	Mt. Solon
Sanger, C. D. and M. G.....	Sangerville	Sangerville
Senger, D. M.....	Mt. Solon	Mt. Solon
Shenandoah Lime Co.....	Strasburg Jct	Strasburg Jct.
Shenandoah Lime & Stone Co.....	Strasburg	Strasburg
Shinault, C. W.....	Deerfield	Deerfield
Shoop, Withers Co.....	Suffolk	Suffolk
Snarr, G. H.....	Wheatfield	Wheatfield
Stuart Land & Cattle Co.....	Elk Garden	Elk Garden
Tazewell White Lime Works.....	North Tazewell	North Tazewell
Thompson, T. W.....	Hinton	Hinton
Wheelbarger-Rumsey Lime Cor.....	Bridgewater	Bridgewater
Whitesell, D. E.....	Stuarts Draft	Stuarts Draft
Wine & Wright.....	Spring Creek	Spring Creek
Wingate & McGhee.....	Roanoke	Roanoke
Woodstock Lime Co., Inc.....	Woodstock	Woodstock

CEMENT.

Although the cement industry may be said to be in its infancy in Virginia, yet the manufacture of this important economic product has been carried on for many years at one locality, and for a less time at another. Natural cement has been burned at Balcony Falls for over

a half century. The demand for a cheap and trustworthy cement for use in the construction of masonry, locks, and walls on the James River canal, led to the discovery of the hydraulic properties of the rock used at this plant. Since that time a natural cement has been manufactured at this locality almost continuously, the James River Cement Company operating the plant at present. The rock used is a blue, argillaceous limestone of Lower Cambrian age, with an average thickness of 12 feet.

There are only two plants for the manufacture of Portland cement in Virginia in operation at present, namely, that of the Virginia Portland Cement Company at Fordwick, Augusta County, and that of the Norfolk Portland Cement Corporation at Norfolk. The Fordwick plant has a capacity of 1,250,000 barrels, and is selling the Old Dominion cement in the North as well as in the South. The materials used by this plant in the manufacture of Old Dominion cement are Lewistown limestone and shale. The Norfolk plant is the first plant built in the South to manufacture Portland cement from shell marl as the principal calcareous material instead of the hard rock—limestone. The marl and clay deposits used by this plant are located on branches of James River near Smithfield and Chuckatuck.

Two additional plants of large capacity have been granted charters for the manufacture of Portland cement in Tidewater (Coastal Plain) Virginia. These are the Jamestown Portland Cement Company's plant to be located at Yorktown, and the Colonial Portland Cement Company's plant to be located near Grove. The raw materials to be used by these plants for the manufacture of Portland cement will be the Miocene marls and clays of the immediate area.

There being only two plants in Virginia producing Portland cement in 1910, the figures of production are combined with those of another subject in order to avoid disclosing individual operations.

Virginia possesses an abundance of raw materials from which cement can be made—an economic resource which will prove of great value. The Appalachian Valley and the various mountains and valleys westward, an area of 350 or more miles long and averaging 50 miles in width, contains limestones and shales equal in value and abundance to those of any other region. The State Geological Survey has issued a

valuable report^a on the Cement Materials west of the Blue Ridge. This report is based on several seasons of careful investigations in the field, and contains an unusually large number of chemical analyses made of the limestones and shales from all parts of the region.

Four prominent sources of cement material obtain in western Virginia. Named in geologic order, these are:

4. Greenbrier (Mississippian) limestone.
3. Lewistown (Helderbergian) limestone.
2. Ordovician (Trenton, etc.) limestones and shales.
1. Cambrian—impure limestone and shale.

Of these, the limestones and shales of Ordovician age are the most promising on account of their abundance, widespread distribution, and usually favorable chemical composition. The Lewistown limestone is now used in the manufacture of Portland cement at Craigsville, Augusta County, and the Greenbrier limestone will probably become an important source of cement material in southwestern Virginia.

The most important cement materials of western Virginia are found in the pure and argillaceous limestones of Cambrian and Ordovician age, and in the calcareous and argillaceous phases of the Ordovician shales. These shales and limestones have a wider distribution and are usually more accessible than other cement rock horizons of the State, such as the Lewistown of Helderbergian age, and the Mississippian or Subcarboniferous (Greenbrier) limestone. In general the entire Valley of Virginia is underlain by the Cambrian and Ordovician limestones, while the shales usually outcrop along the base of the mountains bounding it. In a similar manner, many of the valleys west of the Great Valley show these limestones and shales, higher formations occurring on the separate ridges.

Three classes or groups of hydraulic cements^b are recognized, and materials for their manufacture occur in Virginia. Named in the order of their importance, these are: (1) Portland cement, (2) Natural cement, and (3) Puzzolan cement.

^aBassler, R. S., Virginia Geological Survey, Bulletin No. II-A, 1909.

^bIbid., 1909, pp. 5-32.

Eckel, E. C., Cements, Limes, and Plasters: Their Materials, Manufacture, and Properties. John Wiley and Sons, New York, 1907.

In the manufacture of Portland cement, a finely ground mixture containing lime, silica, alumina, and iron oxide, in exactly determined proportions, is burnt at a temperature approaching 3,000° F. This burning produces a semi-fused mass called "clinker" which, as a last step in the process of manufacture, must be finely ground. The theoretical mixture employed for burning consists of 75 per cent calcium carbonate, 20 per cent iron, alumina, and silica, and 5 per cent allowed for magnesium carbonate and other substances. This ideal composition is seldom realized in nature and, as a rule, an artificial combination is made by mixing limestone or marl with clay or shale. In this case, one part of the clayey materials is generally added to three parts of pure limestone.

The raw material from which natural cement is made is an argillaceous limestone carrying from 13 to 35 per cent of clayey material, of which about 10 to 22 per cent is silica, while alumina and iron oxide together may vary from 4 to 16 per cent. Unlike Portland cement rock, the percentage of magnesium carbonate may run high, the reason for this being that in natural cements the magnesia and lime are regarded as interchangeable. The hydraulic properties do not depend upon the percentage of lime but upon the clayey materials, which are the important factors to consider in the rock analysis.

Limestones having a composition within the limits just indicated are more or less abundant at several horizons in western Virginia, but probably the only one which will meet all the requirements and prove of economic importance is the argillaceous magnesian limestone of the lower part of the Shenandoah group. This rock, although often very similar in lithologic characters to the dolomitic limestone found higher in the Shenandoah group, can be recognized as containing argillaceous matter by the clayey odor given forth when breathed upon.

These limestones (Sherwood) and shales (Buena Vista) form the source of the rock used by the James River Cement Works, near Balcony Falls, Virginia, for making natural cement. These strata are found at various points along the eastern side of the Appalachian Valley in Virginia, so that a considerable supply of the necessary materials should be available.

The erection and operation of Portland cement plants, such as are now proposed in Tidewater Virginia, will have a stimulating influence on the entire industrial activity of the State.

LIST OF CEMENT OPERATORS

OPERATOR	OFFICE	PLANT
James River Cement Co.....	Balcony Falls	Balcony Falls
Norfolk Portland Cement Corporation.....	Philadelphia, Pa	Norfolk
Virginia Portland Cement Co.....	New York, N. Y.....	Fordwick

SAND AND GRAVEL.

The production of sand and gravel in Virginia during 1909 amounted to 847,476 short tons, valued at \$281,177, as compared with 449,234 short tons, valued at \$119,095, in 1908, which represents an increase of 398,242 short tons, or 88.67 per cent, in quantity, and \$162,082, or 73.47 per cent, in value. The 1910 production was 764,321 short tons, valued at \$215,416.

These figures do not represent the total production of sand and gravel in Virginia, as large quantities are produced and utilized each year in the manufacture of brick, and in railway, highway, and sidewalk construction, etc., of which no record of the quantity used is kept and no returns are made to the office of the State Survey. Much the largest proportion of sand used in the State, for which returns are made, is for building and molding. In 1909, there were 33 producers of sand and gravel operating in 20 counties, and in 1910, 33 producers operating in 19 counties. The production of sand in Virginia during 1910, by counties, was as follows: Elizabeth City, 56,272 short tons, valued at \$31,229; Giles, 19,400 short tons, valued at \$11,590; Henrico, 29,391 short tons, valued at \$24,947; Roanoke, 6,500 short tons, valued at \$2,625; Rockingham, 5,005 short tons, valued at \$2,381; other counties,^a 200,552 short tons, valued at \$54,853.

The following table shows the details of the industry, and the comparative quantities and values from 1905 to 1910, inclusive.

^aIncludes Alleghany, Alexandria, Amherst, Carroll, Campbell, Charles City, Norfolk, Princess Anne, Prince George, Pulaski, Scott, Shenandoah, Washington, and Wise.

Production of Sand and Gravel in Virginia, 1905-1910, by uses, in short tons.

	1905		1906		1907	
	Quantity	Value	Quantity	Value	Quantity	Value
Sand—						
Glass					1,246	\$ 4,535
Molding	61,246	\$ 37,899	26,654	\$ 15,466	50,627	30,377
Building	244,572	96,248	272,396	91,265	158,715	67,160
Fire	810	405	1,000	500		
Engine	4,775	3,580	4,370	1,970	10,239	4,603
Furnace	4,212	2,665	21,376	8,028	10,059	4,227
Other	250	330	8,602	4,072	24,334	9,958
Gravel	35,250	13,453	780	650	13,002	2,952
Total	351,115	\$154,580	335,178	\$121,951	268,222	\$123,812

	1908		1909		1910	
	Quantity	Value	Quantity	Value	Quantity	Value
Sand—						
Glass					700	\$ 450
Molding	47,888	\$ 22,568	25,480	\$ 17,241	35,517	24,954
Building	139,742	61,378	368,744	125,208	251,170	88,340
Fire						
Engine	6,651	2,860	3,594	1,585	1,900	1,165
Furnace	11,295	5,500	9,740	4,563	5,339	2,088
Other ^a	670	325	47,631	8,149	22,494	10,628
Gravel	242,988	26,464	392,287	124,431	447,201	87,791
Total	449,234	\$119,095	847,476	\$281,177	764,321	\$215,416

^aIncludes for 1910 polishing and filtration sand.

LIST OF SAND AND GRAVEL OPERATORS

OPERATOR	OFFICE	BED OR PIT
Adair, James	Lurich	Lurich
American Locomotive Co.....	Richmond	Richmond
Appomattox Iron Works.....	Petersburg	Petersburg
Bickford Sand & Gravel Co., Inc.....	Hampton	Hampton
Bolton, John T.....	Norfolk	Hampton
Botto Sand Co., J. L.....	Richmond	Richmond
Bromilaw Brick Co.....	Alexandria	Alexandria
Calhoun & Bro., James W.....	North River	North River
Carter, Mrs. M. E.....	Buddle	Pulaski City
Catawba Valley Ry. & Mng. Co.....	Salem	Salem
Cavedo, W. L.....	Richmond	Richmond
Chesapeake & Ohio Railway Co.....	Basic City	Basic City
Cheshire & Sons, J. W.....	Martinsville	Martinsville
Christian, J. H.....	Providence Forge	Providence Forge
Clinedinst, Jno. S.....	Edinburgh	Edinburgh
Columbia Granite & Dredging Co.....	Washington, D. C.....	Potomac River
Cooper Glass & Silica Co.....	Salem	Salem
Cowardin, S. P.....	Richmond	Richmond
Cuddy, W. T.....	Lurich	Lurich
Curlis, H. C.....	Holdercroft	Holdercroft
Darst, Jno. C.....	Bluff City	Bluff City
Derbyshire, Mrs. M. J.....	Richmond	Richmond
Dills, M. C.....	Bluff City	Pearisburg
Eanes, A. W.....	Roanoke	Roanoke
French & Bro., J. E.....	Curve	Curve
French, K. S.....	Narrows	Narrows
Gibboney Sand Bar Co., Inc.....	Berton	Berton
Gill, E. F.....	Providence Forge	Providence Forge
Gill & Bro., J. M.....	Providence Forge	Providence Forge
Gochenour, J. J.....	Maurertown	Maurertown
Goddin Supply Co., Inc.....	Richmond	Richmond
Harbaugh, Mrs. S. I.....	Richmond (Fairmont)	Richmond
Hoxall, L.....	Providence Forge	Providence Forge
Hunter Farmers Friend Plow Works, The Charles E.....	Fredericksburg	Fredericksburg
International Sand & Material Co.....	Norfolk	Norfolk
Ivanhoe Furnace Co.....	Ivanhoe	Ivanhoe
Jackson, D. E.....	Galts Mill	James River
Johnston, J. Raleigh.....	Bluff City	Bluff City
Laughon & Co., B.....	Pulaski	Laughon Siding
Lillie, Geo. W.....	Richmond	Richmond
Linkous, R. T.....	Narrows	Narrows
Lowmoor Iron Company of Virginia.....	Lowmoor	Lowmoor
Maupin, R. W.....	Waynesboro	Waynesboro
Monger, Jno. H.....	North River	Harrisonburg
Myers, J.....	Roanoke	Roanoke
National Mfg. Co., Inc.....	Lynchburg	Lynchburg
Norfolk Railway & Light Co.....	Norfolk	Norfolk
Norfolk & Southern Railway Co.....	Norfolk	Cape Henry
Perkinson & Finn.....	Petersburg	Petersburg
Port Republic Foundry.....	Port Republic	Port Republic
Presque Gravel Co.....	Norfolk	{ James River Dutch Gap Ocher Petersburg

OPERATOR	OFFICE	BED OR PIT
Pure Silex Co.....	Scottsville	Scottsville
Quarles, A. G.....	Richmond	Richmond
Radford, Mrs. Emma.....	Richmond	Richmond
Richardson, R. E.....	Providence Forge	Providence Forge
Richmond, Fredericksburg & Potomac Rail- way Co.....	Richmond	{ Bowling Green Fredericksburg
Rodgers, James M.....	James River	James River
Rogers, E.	Ivanhoe	Ivanhoe
Sellers, Dr. J. S.....	Weyers Cave	Weyers Cave
Shepherd, Larkin	Appalachia	Appalachia
Slaughter & Griffin.....	Fredericksburg	Fredericksburg
Umstadler, J. M.....	Norfolk	Norfolk
Water Works Supply Corporation.....	Norfolk	Norfolk
Webb J. H.....	Roanoke	Glad Creek
Wills, T. L.....	Lynchburg	Lynchburg

SAND-LIME BRICK.

The term sand-lime brick is used "to cover all brick made by mixing sand or gravel with a relatively small percentage of slaked lime, pressing the mixture into form in a brick mold, and drying and hardening the product either by sun heat or artificial methods."^a

The manufacture of sand-lime brick in Virginia commenced only a few years ago. The total number of sand-lime brick produced in 1908 was 6,181,000 brick, valued at \$36,934, of which 6,123,000 were common brick valued at \$36,184. On account of there being only two producers of sand-lime brick in the State during 1909, the figures are given under "Other products" in the table on page 5, in order to avoid disclosing individual production. The 1910 production of sand-lime brick in Virginia is included under "Other products" in the table on page 6.

LIST OF SAND-LIME BRICK OPERATORS

OPERATOR	OFFICE	WORKS
Cape Henry Granite Brick Corporation	East Radford	East Radford
New River Sandstone Brick Co.....	East Radford	East Radford
Norton Silica Brick Co.....	Norton	Norton
Old Dominion Granite Brick Co.....	Cape Charles	Cape Charles
Virginia Sand-Lime Brick Co.....	Norfolk	Norfolk

^aEckel, E. C. Cements, Limes, and Plasters: Their Materials, Manufacture, and Properties. John Wiley and Sons, New York, 1907.

STONE.

The production of stone has been an important industry in the State for many years, and the product of some varieties, especially granite, has been used in many notable structures. The rocks of Virginia include a large variety and abundance of excellent stone suitable for building, decorative, and other purposes. These have wide distribution over the Crystalline and Mountain provinces, comprising in the former, granite, gneiss, and schist, trappean rocks, in part known to the trade as black granites, slate, quartzite and sandstone, limestone and marble; and in the latter, sandstone, limestone, and marble.

The stone industry is the fourth in importance among those based upon the mineral wealth of the State, being surpassed only by the coal, clay products, and iron ores. The value of the annual production of stone in Virginia from 1900 to 1910, inclusive, is given in the accompanying table.

Value of the annual production of Stone in Virginia from 1900 to 1910, inclusive.

Year	Granite Value	Sandstone Value	Slate Value	Limestone Value	Total Value
1900	\$211,080	\$ 6,000	\$190,211	\$403,318	\$ 810,609
1901	275,701	5,303	178,979	986,177	1,416,160
1902	282,046	2,500	160,951	534,113	979,610
1903	299,335	4,471	115,356	569,205	988,367
1904	510,788	13,522	130,208	442,978	1,097,496
1905	452,390	2,000	146,786	212,660	813,836
1906	340,900	5,100	172,857	260,343	779,200
1907	398,426	(a)	173,670	362,062	935,158
1908	321,530	2,600	194,356	280,542	799,028
1909	488,250	28,574	180,775	342,656	1,040,255
1910	503,106	25,080	148,721	471,903	1,148,810

aSmall value included with West Virginia.

The total value of the different kinds of stone quarried for the period of years for which statistics are given, shows that the quarrying of limestone is the largest industry in stone, with granite next, and slate third. For the past several years granite has been of first importance, although the difference in the annual value of its production

and that of limestone is very small. The variation in limestone production is controlled in large part by the blast furnace conditions where it is used as a flux. The production of sandstone for the period represented in the table is relatively unimportant.

The value of the total production of stone in the State during 1909 was \$1,040,255, while the value for 1910 was \$1,148,810.

GRANITE.

Granites, including the foliated type gneisses, have very wide distribution throughout the Virginia Piedmont region, constituting one of the dominant rock types. The general excellence of the Virginia granites as a building and ornamental stone has long been established in the commercial world. There is not a county within the limits of the Piedmont region that does not contain some granite, but the quarrying industry has thus far been limited to less than half a dozen counties. The principal producing areas of massive granites are distributed along the eastern border of the Piedmont Plateau. They include (1) the Petersburg area, (2) the Richmond area, and (3) the Fredericksburg area. The principal counties composing these areas are Dinwiddie, Chesterfield, Henrico, and Spottsylvania. A small amount of granite has been quarried in a number of other counties within the limits of the Piedmont to supply strictly a local demand.

The granites of the State are chiefly granular aggregates of the minerals quartz, feldspar, and mica. Hornblende and epidote are important minerals in the granites of a few localities in the State, the latter being conspicuous in the variety of granite known as unakite, which is found in Madison, Page, and Grayson counties. Based then on mineral composition, we have the following varieties of Virginia granite: (1) Biotite granite, under which vastly the majority of the granites of the State belong; (2) muscovite granite; (3) hornblende-biotite granite; and (4) epidote granite.

The chemical composition of the granites in the Richmond, Petersburg, and Fredericksburg areas is shown in the table of analyses on page 73.

Analyses of Virginia Granites.(WM. M. THORNTON, JR., *Analyst.*)

Constituents	I	II	III	IV	V	VI	VII	VIII
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Silica (SiO ₂)	72.27	71.51	71.19	70.83	69.48	69.44	69.29	68.45
Alumina (Al ₂ O ₃)	14.30	13.82	14.01	12.70	13.95	15.46	14.07	10.00
Ferric oxide (Fe ₂ O ₃)	1.16	1.76	1.66	2.67	2.82	1.31	2.59	5.71
Ferrous oxide (FeO)	0.97	1.20	1.29	1.36	1.70	1.43	2.03	2.59
Magnesia (MgO)	0.70	0.80	0.44	0.53	1.10	1.01	1.32	3.26
Lime (CaO)	1.56	1.79	2.04	1.88	2.81	2.11	2.76	6.20
Soda (Na ₂ O)	3.46	3.64	3.56	3.49	3.65	3.97	2.89	1.98
Potash (K ₂ O)	5.00	4.63	4.45	4.83	3.45	4.25	2.87	1.18
Water (H ₂ O) -110° C.	0.04	0.17	0.04	0.07	0.04	0.07	0.06	0.18
Water (H ₂ O) +110° C.	0.25	0.31	0.33	0.34	0.50	0.29	0.37	0.62
Titanium oxide (TiO ₂)	0.31	0.33	0.35	0.41	0.47	0.48	0.50	0.20
Manganese oxide (MnO)	trace	0.03	0.02	0.03	0.03	0.03	0.08	0.05
Carbon dioxide (CO ₂)	0.21	trace	trace	trace	trace	trace	trace	trace
Phosphoric acid (P ₂ O ₅)	0.02	0.30	0.34	0.33	0.49	0.22	0.26	0.25
Total	100.25	100.29	99.72	99.47	100.49	100.07	99.09	100.67

- I. Medium-textured and medium gray, biotite granite. Westham granite quarries, 4.5 miles west of Richmond, Chesterfield County.
- II. Medium-textured and medium gray, biotite granite. Lassiter and Petersburg Granite Co.'s quarries, Petersburg, Dinwiddie County.
- III. Fine-grained, dark blue-gray, biotite granite, McGowan, Netherwood, and Donald quarries, Chesterfield County, and Mitchell and Copeland quarry, Henrico County, near Richmond.
- IV. Medium coarse-textured and medium gray, biotite granite. Netherwood, State (Old Dominion), Granite Development Co., Krimm and Middendorf quarries, Chesterfield County, near Richmond.
- V. Fine-grained, dark blue-gray, biotite granite. Cartwright and Davis quarries, near Fredericksburg, Spottsylvania County.
- VI. Medium-textured and medium gray, biotite granite. McIntosh quarry, Chesterfield County, 5 miles west of Richmond.
- VII. Medium coarse-textured, gray, biotite granite-gneiss. Middendorf (Belt Line Railway) quarry, near Manchester, Chesterfield County.
- VIII. Medium coarse-textured, gray, biotite granite-gneiss. Cartwright and Davis quarries, near Fredericksburg, Spottsylvania County.

The Richmond area is the principal granite-producing area in the State. Not less than 20 quarries have been worked within the limits of the area, some of which are very extensive, being worked to a depth of nearly 200 feet. Two grades of granite are quarried, one a fine-grained, dark blue-gray rock, extensively used as monument stock, the

other a coarser grained and lighter colored gray rock admirably suited for building purposes. Both are homogeneous even-granular granites, possessing good working qualities. The fine-grained, dark blue-gray granite is susceptible of a high and permanent polish, and is a superior monumental stone.

Under the general head of granite are included in the trade such crystalline rocks as syenite, diorite, gabbro, and diabase, and the banded rocks known as gneiss and schist.

The production of granite during 1909 was valued at \$488,250, as against \$321,530 in 1908, a gain in value of \$166,720, or nearly 52 per cent. Twelve counties contributed to this production, namely, Alexandria, Amherst, Campbell, Chesterfield, Dinwiddie, Fairfax, Goochland, Greenesville, Henrico, Pittsylvania, Prince Edward, and Stafford. The uses made of the stone and the value of each are given in the table below. The 1910 production of granite in Virginia was valued at \$503,106.

There are given in the tables below the value and uses of the granite and gneiss quarried in Virginia during the years 1900 to 1910, inclusive.

Value of Granite produced in Virginia, 1900-1910, by uses.

Use	1900	1901	1902
Sold in the rough. { Building		\$ 40,763	\$ 21,158
Monumental	\$ 12,000	8,300	12,500
Other		230	
Dressed for building.....	55,296	45,737	28,840
Dressed for monumental work.....	21,461	52,404	51,612
Made into paving blocks.....	16,605	17,253	14,845
Curbing	8,810		29,796
Flagging		7,977	
Rubble			26,255
Riprap	15,833	43,029	17,215
Crushed stone..... { Road-making		9,850	6,133
Railroad ballast	38,850	7,841	25,554
Concrete		42,317	46,588
Other			1,000
Total	\$211,080	\$275,701	\$282,046

Value of Granite produced in Virginia, 1900-1910, by uses.—Continued.

1903	1904	1905	1906	1907	1908	1909	1910
\$ 26,345	\$ 33,613	\$ 31,224	\$ 18,158	\$ 19,350	\$ 26,769	\$ 24,965	\$ 31,841
13,440	17,320	10,415	15,804	8,039	12,664	1,966	3,771
.....	.....	.....	200	.....	1,075	.....	2,375
14,740	48,452	28,950	.....	13,275	4,000	17,750	14,750
43,845	55,608	37,180	16,936	9,787	29,803	9,449	6,300
28,034	30,966	19,220	29,536	18,072	10,173	18,053	28,596
4,582	33,324	8,948	14,339	6,000	6,130	29,100	57,511
5,485	3,516	2,550	1,216	.....	.....	990	1,565
28,449	40,524	28,961	28,477	16,350	18,270	33,321	38,792
22,410	7,630	27,236	31,790	28,852	16,336	1,386	6,989
31,785	12,940	21,175	34,981	59,937	21,670	74,054	40,691
17,400	61,352	69,360	64,386	50,804	92,895	125,704	111,811
60,820	165,043	166,364	85,077	167,960	81,745	147,112	156,894
2,000	500	807	.....	.....	.....	4,400	1,220
\$299,335	\$510,788	\$452,390	\$340,900	\$398,426	\$321,530	\$488,250	\$503,106

In the table below is given the number of granite paving blocks produced in Virginia, by years, from 1904 to 1910, inclusive.

Number and value of Granite Paving Blocks produced in Virginia, 1904-1910.

Year	Number	Value	Average Value per 1,000
1904	1,032,200	\$30,966	\$30.00
1905	913,440	19,220	21.05
1906	1,385,000	29,536	21.32
1907	685,100	18,072	26.38
1908	252,910	10,173	40.22
1909	853,300	18,053	21.16
1910	680,602	28,596	42.02

LIST OF GRANITE OPERATORS

OPERATOR	OFFICE	QUARRY
American Stone Co., Inc.....	Richmond	Boscobel
Andrews & Co., J. W.....	Petersburg	Petersburg
Bedford, A. C.....	Richmond	Butterworth
Belmont Traprock Co., Inc.....	Belmont Park	Belmont Park
Brennan Construction Co. (Gneiss).....	Washington, D. C.....	Chain Bridge
Brown, J. Henry.....	Richmond	Dunbarton Station
Butterworth, R.....	Butterworth	Pride
Cartwright & Davis	Fredericksburg	Fredericksburg
Casey, John B.....	Lynchburg	Lynchburg
Columbia Granite & Dredging Co.....	Washington, D. C.....	Washington, D. C.
Consolidated Quarry Co.....	Washington, D. C.....	Occoquan (near)
Cranford Paving Co. (Gneiss).....	Washington, D. C.....	Washington, D. C.
Danville, City of.....	Danville	Danville
Echols & Co., J. M.....	Lynchburg	Lynchburg
Ford, J. R.....	Lynchburg	Lynchburg
Forge Granite & Lumber Co.....	Falmouth	Falmouth (near)
Fountain Creek Granite Co.....	Norfolk	Hitchcock
Fredericksburg Power Co.....	Fredericksburg	Fredericksburg
Hall, Wm. W.....	Lynchburg	Lynchburg
Harris, H. J.....	Richmond	Boscobel (Harris Sid- ing)
Holland, H. S.....	Richmond	Buffalo Station
Island Granite Co., Inc.....	Richmond	Richmond
James River Granite Co.....	Richmond	Richmond (Holland Sid- ing)
Jones, Harvey	Lynchburg	Lynchburg
Lane Bros. Co.....	Alta Vista	Alta Vista
Lee Stone Co.....	Lee	Lee
Lennox, John	Rio Vista	Rio Vista
Logan, A	Lynchburg, R.F.D.No.3.....	Lynchburg
Lone Jack Stone Co. (Gneiss).....	Lynchburg	Lynchburg
McCloy Granite Co., John A.....	Richmond	Richmond
McGowan, John	Richmond	Manchester
McGranighan, P	Granite	Granite
McIntosh, Hugh (Chesterfield Granite Works)	Granite	Granite
Moncure, Pettitt & Moncure	East Falls Church (or Alexandria C. H.)	Falls Church
Morris & Lipscomb.....	Roanoke	Goodview
Nelson Stone Co., Taylor Gleaves	Lynchburg	Faber
Netherwood, Albin	Richmond	Richmond
Norfolk County Road Board.....	Norfolk	Emporia
Occoquan Stone & Lumber Co.....	Occoquan	Occoquan
Old Dominion Iron & Nail Works.....	Richmond	Belle Isle
Petersburg Granite Co.....	Baltimore, Md	Petersburg
Rockfish Ballast Co.....	Baltimore, Md	Rockfish
Slocombe, W. A.....	Farmville	Farmville
Slocombe & Hall.....	Lynchburg	Lynchburg
Smith & Co., Inc., I. J.....	Richmond	Richmond
Southern Quarry Co.....	Washington	Rockfish
Sunnyside Granite Co., Inc.....	Richmond, R.F.D No. 2.....	Richmond (Dunbarton Station)
Virginia Granite Co.....	Richmond	Dunbarton Station
Virginia Quarrying Corporation.....	Norfolk	Manchester
Virginia State Farm.....	Lassiter	Lassiter
Wakefield Granite Quarries.....	Petersburg	Petersburg
Wray, A. J.....	Richmond	Granite

MARBLE.

Marbles are found in the Mountain province west of the Blue Ridge and in the Piedmont province to the east, but there has been but slight attempt to develop them, owing chiefly to a lack of definite knowledge of their extent and quality. Bands occur in some of the limestones of the Mountain province, especially in the Shenandoah and Chickamauga formations, of a color and texture which adapt them to ornamental purposes. These show a variety of color and texture. White, gray, red, and black colors are found. These marbles have not received the attention which they apparently merit in places, and the developments thus far are slight.

Onyx marbles are fairly abundant in the limestone caves and caverns of the Valley region, but it is probable that these will rank as "uniques" rather than objects of commercial value. Large deposits of onyx marbles are found near Bridgewater in Rockingham County, but they have not been investigated and very little is known of their quality.

Marbles of excellent quality occur in the vicinity of Goose Creek, Loudoun County. Samples of the white marble are not excelled for purity of color, fineness of grain, and general excellence, by that of any other marble in the United States. At Goose Creek, the marble bed is about 52 feet thick and has been worked to a considerable depth. The varieties shown are chiefly white, but there occur, also, banded blue and white, serpentinized white and green, pink and white, and green and white. These beds are pure, and the stone is of great beauty and takes a good polish. The lack of transportation facilities has thus far prevented extensive quarrying.

Undeveloped areas of marbles are known in Grayson, Campbell, Nelson, and Pittsylvania counties. Openings were made in some of these many years ago and the stone burned into lime.

There has been no production of marble in Virginia for several years.

LIMESTONE.

Limestone has its greatest distribution in the region west of the Blue Ridge where it forms one of the dominant rock types. It has had only a limited use for building purposes, but has been extensively

quarried for use as a furnace flux, for lime-making in building and agriculture, for road metal and ballast, for concrete, and for the manufacture of Portland and natural cements. Four prominent sources of limestone obtain in this region, which, named in geologic order, are:

4. Greenbrier (Mississippian) limestone.
3. Lewistown (Helderbergian) limestone.
2. Ordovician (Trenton, etc.) limestone.
1. Cambrian limestone.

Of these four principal divisions of limestones, the Cambrian and Ordovician limestones constitute the Shenandoah (Valley) limestone group, which is the most persistent limestone group in the State. It is the underlying or basement rock of the Great Valley (Shenandoah) of Virginia. The most important and only limestone which has been used in buildings is the Shenandoah limestone of the Great Valley. In its normal development, it is probably not less than 3,500 feet thick and in places it is much thicker. It has a wide range in composition and is divisible into several different members. The most important member of the Shenandoah limestone for building stone is the Natural Bridge limestone, which is usually a heavy-bedded, dark blue to gray magnesian limestone, frequently dolomitic. Quarries have been opened in it, in many places through the Valley region, and the stone used locally for building purposes.

The Lewistown and Greenbrier limestones have not been used for building purposes, but each has been quarried in places, especially the Lewistown, and used for fluxing the iron ores at the blast furnaces.

The value of limestone produced in the State during 1909 was \$342,656, as compared with \$280,542 in 1908. This represents a gain of \$62,114, or slightly over 22 per cent, in value. This increase in production was due chiefly to an increased production of limestone for use as railroad ballast and fluxing purposes. There were 32 producers of limestone operating in fourteen counties of the State, as against 30 producers in 1908. There is given below in tabular form the value of limestone produced in Virginia in 1909, by counties.

Value of Limestone produced in Virginia in 1909, by counties.

County	Value
Augusta	\$ 5,081
Botetourt	59,695
Roanoke	13,511
Rockbridge	37,281
Other counties ^a	227,088
Total	\$342,656

^aIncludes Alleghany, Giles, Lee, Loudoun, Rockingham, Russell, Shenandoah, Tazewell, Washington, and Wythe.

The production of limestone in Virginia during 1910 was valued at \$471,903, which represents an increase in value over the 1909 production of \$29,247.

There were 37 producers of limestone in the State during 1910, operating in the following 15 counties: Alleghany, Augusta, Botetourt, Giles, Loudoun, Pulaski, Roanoke, Rockbridge, Shenandoah, Smyth, Tazewell, Warren, Washington, Wise, and Wythe.

The production of limestone in Virginia from 1902 to 1910, inclusive, and the uses for which it was quarried are given in the table below:

Production of Limestone in Virginia from 1902 to 1910, by uses.

	1902	1903	1904	1905	1906
Rough building	\$ 41,355	\$ 5,325	\$ 8,800	\$ 5,390	\$ 3,448
Dressed building			360	700	1,680
Paving					
Curbing					275
Flagging					
Rubble			168		
Riprap		22		120	323
Crushed stone:					
Road making		300	210	5,254	160
Railroad ballast	7,875	16,205	32,371	9,333	16,050
Concrete	11,580	9,238	5,668	11,187	18,700
Flux	220,001	199,989	117,882	180,676	219,707
Unspecified	11,318	1,665			
Total	\$534,113	\$569,205	\$442,978	\$212,660	\$260,343

Production of Limestone in Virginia from 1902 to 1910, by uses.—
Continued.

	1907	1908	1909	1910
Rough building	\$ 3,170	\$ 1,870	\$ 715	\$ 125
Dressed building	1,130	2,950	129	.....
Paving	500	.....	15	45
Curbing .....	.....	79	.....	750
Flagging .....	.....	110	7	.....
Rubble .....	.....	.....	3,000	3,188
Riprap .....	.....	3,377	.....	1,805
Crushed stone:				
Road making	37,000	30,159	31,076	20,056
Railroad ballast	12,269	45,541	84,883	108,129
Concrete	32,326	26,604	8,068	36,849
Flux	275,517	169,847	213,444	294,668
Unspecified	150	5	1,319	6,288
Total	\$362,062	\$280,542	\$342,656	\$471,903

LIST OF LIMESTONE OPERATORS

OPERATOR	OFFICE	QUARRY
Abingdon Construction Co.....	Abingdon	Abingdon
Alleghany Lime Co., Inc.....	Christiansburg	Houchin Station
Andrews & Co., Inc., T. C.....	Norfolk	Norfolk
Beinkampen Lime Co.....	Radford	Radford
Bertha Mineral Co., Inc.....	Pulaski	Austinville
Bradley, Samuel A.....	Newport	Newport
Bristol Lime & Stone Co., Inc.....	Bristol, Va.-Tenn	Benhams (near)
Bunn, J. E.....	Big Stone Gap.....	Big Stone Gap
Burks, Jas. L.....	Compton Bridge	Saltpetre Cave
Carpenter & Boxley.....	Roanoke	Pembroke
Carter, Walter H.....	Buchanan	Buchanan or Lithia
Childress, J. S.....	Christiansburg	Christiansburg
Chiles, C. M.....	Strasburg	Strasburg
Church, E. W.....	Staunton	Craigsville
Clifton Forge, City of	Clifton Forge	Clifton Forge
Compton, C. W.....	Roanoke	Compton Bridge
Compton Bridge Stone Corporation.....	Indian Rock	Compton Bridge
Covertson, Eli and Samuel.....	Pelton	Seven Fountains
Crann, J. N.....	Mossy Creek	Mossy Creek
Cregger, R. C.....	Wytheville	Wytheville
Cross & Mays.....	Eagle Rock	Eagle Rock
Culbert, W. F.....	Marion	Marion
Davidson, S. C.....	Max Meadows	Wytheville
Davis, C. W.....	Blacksburg	Blacksburg
Dillon's Sons, E.....	Indian Rock	Buchanan and Indian Rock
Eagle Rock Lime Co.....	Richmond	Eagle Rock
Eureka Lime Co.....	Vicar Switch	Vicar Switch
Fellers Stone Co.....	Roanoke	Roanoke
Fellsworth Lime Works.....	Staunton	Staunton
Fisher & Co., S. E.....	Strasburg	Strasburg Jet.
Flickwir, David W.....	Roanoke	Roanoke

OPERATOR	OFFICE	QUARRY
Fox, J. W.	Ottobine	Ottobine
Fringer, C. F.	Buchanan	Buchanan (or Lithia)
Gochenour, J. J.	Mauertown	Mauertown
Goshen Iron Co.	Goshen	Bells Valley and Craigs- ville
Grove Lime Co., M. J.	Limekiln, Md	Stephens City
Haldeman, H. F.	Churchville	Churchville
Hall, George B.	East Radford	Snowville
Harris, J. A.	Stuarts Draft	Stuarts Draft
Herbaugh, Robert L.	Zepp	Zepp
Hoag Co., William N.	Strasburg or New York, Strasburg N. Y.	
Hogshead, Charles A.	Mossy Creek	Mossy Creek
Horneck Construction Co.	Cumberland	Gate City
Huggins & Co., H. H.	Roanoke	Roanoke
Ivanhoe Furnace Co.	Ivanhoe	Ivanhoe
Keller, J. H.	Fishers Hill	Fishers Hill
Kinzer & Vermillion	Tazewell	Tazewell
Kiracofe, C. S.	Bridgewater	Bridgewater
Kirk, John Y.	West Norfolk	West Norfolk
Kline, J. Harvey	Vaocluse Station	Vaocluse Station
Larner & Co., William	Staunton	Staunton
Leesburg Lime Co., Inc.	Leesburg	Leesburg
Lexington, Town of	Lexington	Lexington
Limeton Lime Co.	Limeton	Limeton
Linville Lime Co.	Linville	Linville
Lowener, C. A.	Harrisonburg	Rockingham
Lone Jack Stone Co.	Lynchburg	Lynchburg
Longdale Iron Co.	Longdale	Longdale
Lowmoor Iron Co. of Virginia	Lowmoor	Lowmoor
Luray Lime Co.	Eura	Luray
McCoy, G. W.	Springwood	Springwood
McGhee & Co., P. R.	Roanoke	Roanoke
McIlwee, C. E.	Zepp	Zepp
McKimmy, A. G.	Luckets	Luckets
Markley, C.	Roanoke	Roanoke
Mathews Curtis Co., Inc.	Clifton Forge	Clifton Forge
May, A. J.	Tazewell	Tazewell
Miller, G. Ed.	Bridgewater	Bridgewater
Moore Lime Co.	Richmond	Eagle Rock
Myers & Neville.	Clifton Forge	Clifton Forge
Natural Bridge Lime Co.	Glasgow	Sherwood
New River Lime Co.	Ripplemead	Ripplemead
Oak Ridge Lime Firm.	Mt. Solon	Mt. Solon
Oriskany Ore & Iron Corporation	Iron Gate	Mt. Marble
Orndorff, M. M.	Oranda	Oranda
Oyler, Geo. V.	Winchester	Winchester
Powhatan Lime Co.	Strasburg	Strasburg
Pruver, W. W.	Friendship	Friendship
Pulaski Iron Co.	Pulaski	Patterson and Ivanhoe
Pullins, A. C.	Mount Sidney	Mount Sidney
Rawley, N. B.	Churchville	Churchville
Rife Bros	Timberville	Timberville
Riverton Lime Co	Riverton	Riverton
Riverton Lime Quarry Co.	Leesburg	Leesburg
Roanoke Stone & Lime Co., Inc.	Roanoke	Lithia

OPERATOR	OFFICE	QUARRY
Rockbridge Lime & Stone Co.....	Lexington	Lexington
Rockdale Lime Co.....	Toms Brook	Toms Brook
Rule, Pendleton	Abingdon	Abingdon
Sandridge, W. P.....	Goshen Bridge	Panther Gap
Shenandoah Iron & Coal Co.....	Liberty Furnace	Liberty
Shenandoah Lime Co.....	Strasburg Jct	Strasburg Jct.
Shenandoah Lime & Stone Co.....	Strasburg	Strasburg
Shoop Withers Co.....	Suffolk	Suffolk
Snarr, G. H.....	Wheatfield	Wheatfield
Snyder, E. A.....	Buchanan	Springwood
Staunton, City of.....	Staunton	Staunton
Stickley & Orndorff.....	Oranda	Oranda
Stoutamine, Jacob	Roanoke	Roanoke
Stuart Land & Cattle Co.....	Elk Garden	Elk Garden
Sutton, W. B.....	Mendota	Fugates Hill
Tazewell White Lime Works.....	North Tazewell	North Tazewell
Thompson, T. W.....	Hinton	Harrisonburg
Valley Turnpike Co.....	Mt. Jackson	Mt. Jackson
Vaughan Construction Co.....	Roanoke	Roanoke
Virginia Iron, Coal & Coke Co.....	Bristol, Tenn	Barren Springs, Buchanan, and Radford
Webb, J. H.....	Roanoke	Roanoke
Wells & Hanger.....	Staunton	Staunton
West End Furnace Co.....	Roanoke	Buchanan
Wheelbarger-Rumsey Lime Corp.....	Bridgewater	Bridgewater
Whitesell, D. E.....	Stuarts Draft	Stuarts Draft
Woodstock Lime Co., Inc.....	Woodstock	Woodstock
Wytheville Town Quarry	Wytheville	Wytheville

SANDSTONE.

Sandstones and quartzites occur in each of the three larger divisions of the State, but quarrying has been limited to only a few of the more accessible areas. There are large areas of these rocks not yet developed because chiefly of their remoteness from lines of railway and large centers.

The principal sandstone and quartzite formations in the State may be classified as follows:

COASTAL PLAIN:

1. Cretaceous sandstones along the "fall-line."

PIEDMONT PLATEAU:

2. Older quartzites in crystalline area of unknown age.
3. Newark (Triassic) sandstones.

APPALACHIAN MOUNTAINS:

4. Cambrian sandstones.
5. Silurian sandstones.
6. Devonian sandstones.
7. Carboniferous sandstones.

Excepting the areas of Triassic (Newark) sandstones, the quartzites and sandstones found east of the Blue Ridge, in the Crystalline area, are of unknown age. There occur an abundance and variety of this type of rock within the limits of the Piedmont. The rock has been quarried in many places, in years past, for use as a general constructional stone, and quarries are operated at present in a number of counties principally for crushed stone for road construction, ballast, and concreting. The stone ordinarily is firm, hard and compact, highly siliceous, very durable, and is admirably adapted to the uses made of it.

The Cretaceous and Triassic sandstones are practically the only ones which have been quarried and the stone shipped beyond the limits of the State. Of these, the Cretaceous sandstone, which occurs along the western margin of the Coastal Plain, was formerly extensively quarried in the vicinity of Aquia Creek and on the Rappahannock River near Fredericksburg. The stone from these quarries was used chiefly in the construction of many of the older public buildings in Washington. These quarries were abandoned many years ago, largely, it is said, because of the unfitness of the stone for exposed work.

There are seven areas of Triassic rocks, composed in part of sandstone, distributed over the crystalline region east of the Blue Ridge. These comprise parts of twenty counties, and are designated as follows: (1) New York-Virginia area, (2) Richmond area, (3) Danville area; (4) Farmville area, (5) Scottsville area, (6) Barboursville area, and (7) Taylorsville area. The Triassic sandstone has been quarried in the vicinity of Manassas, Prince William County, and in the vicinity of Leesburg and Oatlands, Fauquier County. The Manassas quarries have yielded a stone that could be used with pleasing effects in a variety of combinations, and in quality not inferior to that in the more northern and eastern states.

The Cambrian sandstones are chiefly limited in distribution to the western base of the Blue Ridge and have been quarried locally, especially east of Basic, Augusta County, for railroad ballast. Sandstones of Silurian age have wide distribution west of the Blue Ridge, but they vary much in color, texture, and structure. Although possessing the essential properties in places requisite for a general construc-

tional stone, the Silurian sandstones have not been quarried except for immediate local needs. The Oriskany sandstone of Devonian age is generally too friable to make a good building stone.

The Carboniferous comprises the greatest total thickness of sandstones of any single geologic system in the State. The rocks belonging to this system are limited in distribution to certain parts of the region west of the Blue Ridge, and are in part Mississippian and in part Pennsylvanian in age. The Carboniferous sandstones possess those qualities in some localities which make them desirable for building purposes, but as yet they have seldom been quarried, owing largely to a lack of demand for the stone and ample transportation facilities. They have been quarried in places in southwest Virginia for local use as a building stone and for heavy masonry.

The production of sandstone in the State is slight, and it varies greatly according to the local demands. The value of the annual production of sandstone from 1900 to 1910, inclusive, is shown in the accompanying table.

Value of Sandstone production in Virginia, 1900-1910.

Year	Value
1900.....	\$ 6,000
1901.....	5,303
1902.....	2,500
1903.....	4,471
1904.....	13,522
1905.....	2,000
1906.....	5,100
1907.....	(a)
1908.....	2,600
1909.....	28,574
1910.....	25,080

aSmall value included with West Virginia.

LIST OF SANDSTONE OPERATORS

OPERATOR	OFFICE	QUARRY
Gaithers Construction Co.....	Manassas	Nokesville
Hall, L. M.....	Wise	Wise
Mathews Curtis Co., Inc.....	Clifton Forge	Basic City
Peak Creek Sandstone Co.....	Pulaski	Pulaski
Portner Brown Stone Co.....	Manassas	Manassas
Warden & Hailley.....	Pulaski	Pulaski
Wood, J. R.....	Lynchburg	Lynchburg

SLATE.

Slate suitable for roofing and other purposes has been found in many localities within the limits of the State, and quarries have been worked in Albemarle, Amherst, Buckingham, Fauquier, and Fluvanna counties. There are five principal slate areas and several minor belts in Virginia, which, named in the order of their present commercial importance, are: (1) The Arvonian belt in Buckingham and Fluvanna counties; (2) the Keswick-Esmont belt in Albemarle County; (3) the Snowden belt in Amherst and Bedford counties; (4) the Warrenton belt in Fauquier and Culpeper counties; and (5) the Quantico belt in Spottsylvania, Stafford, and Prince William counties. These areas are being studied and mapped by the State Geological Survey when, upon the completion of the chemical and microscopical studies, a volume will be published for distribution. Of the slate areas worked, the Arvonian and Keswick-Esmont belts are commercially the most important at present.

The slate produced in the Arvonian district is the most widely known in the South. The quarries are distributed along Hunts Creek, for some distance north-northeast and south-southwest of Arvonian, a station on the Buckingham Branch of the Chesapeake and Ohio Railway, which is the shipping point. The quarries are very extensive, the largest averaging about 500 feet along the cleavage, 350 feet across, and 350 feet deep. The bedding and cleavage of the slate are identical, striking N. 33° to 37° E., and dipping 70° to 90° southeast, with a probable average of about 85°. The slate is very dark gray in color, with a faint greenish hue; is of minutely granular crystalline texture, and very lustrous surface. According to Dale, it is slightly graphitic and magnetitic, does not effervesce in cold dilute hydrochloric acid, and is very sonorous. Dale gives the constituents of the slate in order of their abundance as muscovite and sericite, quartz, biotite, carbonate, graphite (or carbonaceous matter), pyrite, chlorite, magnetite, with accessory plagioclase, zircon, hematite, tourmaline, and rutile.

Although Dale's results on the microscopic study of the Arvonian slate show the presence of some carbonate, an appreciable amount of ferrous carbonate can not be present, for the use of these slates on

buildings in Richmond more than 60 years ago, and on buildings near the quarries for more than a century, shows no discoloration whatever. Strength and durability would naturally follow from the highly crystalline character of this slate.

The Arvonian belt of slate extends for some distance northeastward across the James River into Fluvanna County, and has been opened at several places in the vicinity of Bremono, Fork Union, and Palmyra. Some recent prospecting of the slate in the vicinity of Fork Union and Palmyra, by the Old Dominion Slate and Cement Company, gave most encouraging results as to quantity and quality of the slate, and it is expected that systematic quarrying by this company will be begun at an early date.

About 20 miles west-northwest of the Arvonian belt is the Keswick-Esmont slate belt. It has been prospected at several places, and quarries producing an excellent grade of slate are operating in the vicinity of Esmont.

The Snowden slate belt occurs on the southeast side of the Blue Ridge, in the vicinity of Snowden station, in the southwest part of Amherst County. The belt has been prospected in a number of places, and the Williams Bros. Slate Company has successfully operated a quarry about three miles north-northwest of Snowden. The slate strikes N. 65° E., and has quartzite southeast of it which has been referred to the Cambrian. The cleavage strikes N. 45° E. and dips S. 60° E., and is cut by the original bedding planes which are quite strongly marked at an angle of 45° and more. The slate is very dark gray, has a minutely granular texture, moderately smooth cleavage, but with little lustre. It resembles the Arvonian slate in not effervescing with cold dilute hydrochloric acid and in being quite sonorous, but differs from it in not being graphitic nor magnetitic. Arranged in order of abundance, the chief constituents are, according to Dale, muscovite (sericite), quartz, chlorite, kaolin, pyrite, carbonate, rutile, and carbonaceous matter. It is used exclusively for roofing and is a superior slate, though less crystalline than the Arvonian slate.

In Fauquier and Culpeper counties, slate outcrops are traceable to the north and south of the Rappahannock River in the vicinity of White Sulphur springs. The slate outcrops about one mile south of the

springs, and is traced northward for a distance of two miles, with a minimum width of half a mile. The strike of the cleavage over most of the belt is N. 25° to 30° E., with a change in strike to an east-westward direction about three-quarters of a mile south of the springs. The slate is black, of moderately fine texture, and has but little lustre. It is very carbonaceous, shows much pyrite in places, contains no magnetite, does not effervesce with cold dilute hydrochloric acid, and has an argillaceous odor. In the northeasterly opening, Dale gives the chief constituents of the slate, arranged in the order of abundance, as carbonaceous matter, quartz, muscovite, feldspar, pyrite, and chlorite.

Investigations of this belt by the State Geological Survey indicate that pyrite is not present in harmful quantity in all parts of the belt, but that important commercial slate is found, and was quarried on a small scale from a number of openings many years ago, and used locally for roofing purposes.

In Prince William, Stafford, and Spottsylvania counties is one of the most extensive belts of slate in the State. This has been named the Quantico belt by Darton, from the creek by that name. No developments have been made on this belt, and it is not known whether it contains slate of commercial grade or not, but it is being carefully investigated by the State Geological Survey.

The total production of slate in Virginia during 1909 amounted to 40,880 squares, valued at \$180,775, as against 41,678 squares, valued at \$194,356 in 1908, a decrease of 798 squares in quantity and \$13,581 in value. The 1910 production amounted to 31,787 squares, valued at \$148,721. These figures when compared with the 1909 production represent a decrease of 9,093 squares in quantity and \$32,054 in value. In 1910, there were seven producers of slate operating in two counties, namely, Albemarle and Buckingham, with the principal part of the production from Buckingham County. The amount and value of the annual production from 1903 to 1910, inclusive, are given in the accompanying table:

Production of Slate in Virginia, 1903-1910.

Year	Roofing Slate Number of Squares	Value	Average Price Per Square
1903	29,646	\$115,356	\$3.89
1904	31,852	130,208	4.08
1905	36,102	146,786	4.07
1906	39,068	172,857	4.42
1907	37,172	173,670	4.68
1908	41,678	194,356	4.66
1909	40,880	180,775	4.42
1910	31,787	148,721	4.68

The number of squares, as given in the above table, includes both first and second qualities, and the average price per square does not give a fair indication of the prices obtained for most of the stock.

LIST OF SLATE OPERATORS

OPERATOR	OFFICE	QUARRY
Arvonian Slate Co., Inc.	Lynchburg	Arvonian
Buckingham Slate Co., Inc.	Richmond	Arvonian
Carbolane Slate Co.	Esmont	Esmont
Ferncliff Slate Co.	Rochester, N. Y.	Arvonian
James River Slate Co.	New Haven, Conn.	New Canton
LeSeuer Slate Co., Inc.	Orebank	Orebank
Old Dominion Slate & Cement Co.	Palmyra	Palmyra
Penlan Slate Co.	Penlan	Penlan
Pitts, A. L.	Arvonian	Arvonian
Richmond Slate Co., Inc.	Richmond	Arvonian
Standard Slate Corporation	Esmont	Esmont
Victory Buckingham Slate Co.	Penlan	Penlan
Virginia Slate Co., Inc.	Arvonian or Farmville.	Arvonian
Williams Bros. Slate Co.	Snowden	Snowden
Williams Slate Co.	Arvonian	Arvonian

CRUSHED STONE.

The state-wide interest in good roads construction and improvement, and in the building of new lines of railway in Virginia during the past year, have greatly increased the demand for crushed stone. This material is used exclusively for road-making, railroad ballast, and concrete. The value of the production of crushed stone in Virginia in 1909 was \$470,897 and in 1910, \$474,430, as compared with \$298,614 in 1908.

Road Materials.—The road-building materials of Virginia are abundant and vary greatly in character. Nearly all varieties of stone used in highway construction are found in quantity in many sections of the State. The question of transportation is so important a factor that usually the best materials for road making can not be used in areas far removed from the sources of supply.

In Western Virginia—the Mountain province west of the Blue Ridge—limestones, sandstones, and shales are the principal rocks. Of these, limestone is the best suited for road making. It is found in quantity over most of the region, is easily worked, has good cementing or binding quality, but does not possess the durability of the igneous rocks when used as road metal.

In Middle Virginia—the crystalline area or Piedmont Plateau—the rocks are largely crystalline metamorphic igneous and sedimentary types. These comprise granite, gneiss, schist, and the basic igneous types commonly known as trap, with local areas of slates, limestones, and quartzites. Of these, and in fact of all rocks, the basic igneous types, known as trap, make the best road metal. These rocks are tough and difficult to work, possess a high cementing value, great resistance to wear, and afford a valuable and permanent road metal. These rocks are widely distributed, occurring in practically every county in the Piedmont region.

In Eastern Virginia—the Tidewater or Coastal Plain province—the rocks are of comparatively recent geologic age (late Mesozoic and Cenozoic), and consist chiefly of unconsolidated beds of sand, gravel, clay, and marl, which may be locally indurated by a cement either of iron oxide or carbonate of lime. The gravels and marls, when properly used, are of value in road construction, but they afford a less permanent road metal than the igneous rocks. The oxide of iron and carbonate of lime act as the cementing materials.

Ballast and Concrete.—With the exception of the marls, the materials used for railroad ballast and concrete are the same as those employed in road construction. The requirements are somewhat different from those of good road metal, since little or no binding power is required in railroad ballast, and cementing material is added in concrete.

The value of crushed stone produced in Virginia from 1903 to 1910, by years, is given in the table below.

Value of Annual Production of Crushed Stone in Virginia, 1903-1910.

Year	Granite, Gneiss, Etc.			Limestone			Total
	Road	Ballast	Concrete	Road	Ballast	Concrete	
1903	\$31,785	\$ 17,400	\$ 60,820	\$ 300	\$16,205	\$ 9,238	\$135,748
1904	12,940	61,352	165,043	210	32,371	5,668	277,584
1905	21,175	69,360	166,364	5,254	9,333	11,187	282,673
1906	34,981	64,386	85,077	160	16,050	18,700	219,354
1907	59,937	50,804	167,960	37,000	12,269	32,326	360,296
1908	21,670	92,895	81,745	30,159	45,541	26,604	298,614
1909	74,054	125,704	147,112	31,076	84,883	8,068	470,897
1910	40,691	111,811	156,894	20,056	108,129	36,849	474,430

FURNACE FLUX.

Limestone, used in smelting operations for flux, is quarried and shipped to the numerous blast furnaces in the State. The utilization of limestone as flux constitutes the largest consumption of the Virginia stone. Each of the principal limestone horizons in western Virginia supplies some stone as flux to the iron furnaces, but the Cambro-Ordovician and Lewistown (Helderbergian) limestones are the principal sources of stone for this purpose. Of the total production of limestone in the State in 1909, 62.29 per cent was sold as flux and utilized in the blast furnaces, and in 1910, 62.44 per cent was sold for the same purposes. Table on page 80 shows the total value of the limestone production in Virginia for all uses in 1909 to be \$342,656, of which \$213,444 was the total value of limestone used as flux. The 1910 production of limestone was valued at \$471,903, of which \$294,668 worth was used as flux.

There are given in the table below the annual production and value of limestone as furnace flux in Virginia from 1902 to 1910, inclusive.

Production of Furnace Flux in Virginia, 1902-1910, in long tons.

Year	Quantity	Value
1902.....	565,704	\$ 220,001
1903.....	499,108	199,989
1904.....	273,826	117,882
1905.....	393,662	186,676
1906.....	467,341	219,707
1907.....	541,610	275,517
1908.....	290,487	169,847
1909.....	388,746	213,444
1910.....	540,264	284,668

ABRASIVE MATERIALS.

Under this head are included corundum, emery, and millstones, but in 1909 and 1910 the only abrasive material produced was millstones, which were quarried in Montgomery County.

Corundum and Emery.

The occurrence of corundum and emery has been noted in Virginia, but neither has been produced on a commercial scale.

Corundum.—The principal occurrence of corundum is in Patrick County, about two miles from Stuart, where it occurs on a knob of Bull Mountain, in mica schists. It is a grayish-white to white and colorless and, according to Pratt, is readily cleaned. Tests made for the cleaned product at this locality show that the corundum is well adapted to the manufacture of the vitrified wheel.

Emery.—Emery, a granular corundum of black or grayish-black color and containing magnetite or hematite intimately mixed, is found in considerable quantity a short distance west of Whittles in Pittsylvania County. Two openings about 300 feet apart and 20 feet deep have been made on apparently parallel “veins.” Numerous smaller openings have been made near by. The rocks inclosing the emery are probably altered amphibolites or pyroxenites.

Millstones (Buhrstones).

Under this name is included a siliceous conglomerate of quite variable structure, used in the form of flat-circular disks for grinding purposes.

About five miles west of Blacksburg, in the vicinity of Prices Fork, Montgomery County, a sandstone-conglomerate occurs in Brush Mountain, in which quarries have been opened for a distance of three miles. The rock is somewhat variable in color, but is usually of some light shade, white or gray. Likewise variation in the size of the pebble is shown. The rock is made up of well-rounded pebbles of quartz compactly imbedded in a fine siliceous sandstone matrix, the whole forming an exceedingly tough and hard mass. This rock is known on the market as "Brush Mountain" stone. Practically the same variation in the sizes of stone made at the different quarries obtains. The sizes of stone produced in 1910 as reported to the State Survey office were, 12, 14, 16, 20, 24, 26, 30, 36, 42, 48, and 54 inches.

The grindstones made from this rock are of excellent quality and find a ready market. The geologic age of the "Brush Mountain" stone is Mississippian (Lower Carboniferous).

Similar siliceous conglomerates occur in other counties of the State, especially in some of the counties of the Mountain province, but the Brush Mountain quarries, in Montgomery County, are the only producing ones.

The production of millstones in Virginia during 1909 was valued at \$12,348, as against \$7,954 in 1908, an increase in value of \$4,394, or 55.5 per cent. The value of the millstone production for 1910 amounted to \$5,273, a decrease of \$7,075, or nearly 57.3 per cent in comparison with the figures for 1909. The value of millstones produced in Virginia for the years 1902 to 1910, inclusive, follows below in tabular form.

Value of Millstones Produced in Virginia, 1902 to 1910, inclusive.

Year	Value
1902.....	\$ 11,435
1903.....	9,812
1904.....	4,759
1905.....	8,186
1906.....	15,611
1907.....	4,684
1908.....	7,954
1909.....	12,348
1910.....	5,273

LIST OF ABRASIVE OPERATORS

OPERATOR	OFFICE	QUARRY
Olinger, R. L.....	Prices Fork.....	} Brush Mountain, near Prices Fork
Price, A. S.....	Prices Fork.....	
Price & Co., E. S.....	Prices Fork.....	
Price & Son, Z.....	Blacksburg.....	
Standard Millstone Co.....	Vicar Switch.....	

SILICA.

Under this heading are included three forms of silica which have rather wide distribution in the State. These are quartz, chert, and diatomaceous earth.

QUARTZ.

Quartz has wide distribution in the State. It occurs as an essential constituent in granite, gneiss, and mica schist of the crystalline area; as the dominant constituent in the sandstones, quartzites, and conglomerates of the Piedmont and Valley regions; and in the form of sand over parts of each of the larger geologic divisions of the State. A principal occurrence of quartz in Virginia, that is of commercial value, is in the form of pegmatite dikes and quartz veins penetrating the older metamorphic rocks of the Piedmont region.

There was no reported production of quartz in 1909 and 1910.

CHERT.

Chert, known also as hornstone, a term applied to any impure flinty rock, including the jaspers, is a chalcedonic variety of silica. Chert has wide distribution in certain beds of the Shenandoah or Valley limestone of the Valley region, in the form of irregular nodular masses of light nearly white, red, brown, and black colors. No special use has yet been made of the Virginia chert.

DIATOMACEOUS EARTH.

Diatomaceous earth, known in the trade under the name of "silica," "infusorial earth," or "tripoli," is composed of minute shells or tests of microscopic plants known as diatoms. It was first reported from the vicinity of Richmond, Virginia, and for that reason received the name of "Richmond earth," under which term it is sometimes referred to in the literature. Because of its occurrence at Bermuda Hundred, on the James River, it has also been called "Bermuda earth."

The first bed of diatomaceous earth of any extent discovered in this country was in the Richmond area. It is known as the Richmond bed, which extends from Herring Bay on the Chesapeake, Maryland, to Petersburg, Virginia, and probably beyond. It is not less than 30 feet in thickness in places, though very impure at times. It is of Miocene age, and is exposed along the numerous streams close to their crossings from the crystalline rocks on to the sediments of the Coastal Plain.

The diatomaceous earth has been dug from time to time in the vicinity of Richmond for commercial use. There has been no reported production of this material in Virginia for several years.

MICA.

Commercial mica, which includes the varieties known as muscovite and phlogopite, usually occurs in pegmatite dikes penetrating granites, gneisses, and schists. The pegmatites usually consist of a coarse crystallization of quartz and feldspar in varying proportions, with or without mica, and other accessory minerals. They vary in thickness from a few inches to several hundred feet, are often irregular in outline, and may be parallel to or break across the schistosity of the inclosing rocks. In small veins the mica is frequently too small in size to have commercial value. Both the quartz and the feldspar of the pegmatites are of value, and are sometimes mined with the mica and utilized in the manufacture of pottery and for abrasives.

Pegmatites containing commercial mica are somewhat abundantly developed in many of the Virginia Piedmont counties, and many excellent surface indications for mica occur, but as yet prospecting and mining have been confined to only a few of them. Mica has been either prospected or mined in the following counties in Virginia: Near Amelia and Jetersville, Amelia County; near New London and at Lowry, Bedford County; Goochland County; near Chatham, Pittsylvania County; near Axton and at Ridgeway, Henry County; near Hewlitts, Hanover County; near Farmville and at Prospect, Prince Edward County; Amherst and Charlotte counties. Indications of mica occur also in Buckingham, Caroline, Cumberland, Franklin, Powhatan, and Spottsylvania counties.

The mica of the Amelia County district occurs in pegmatites cutting a thinly foliated, biotite gneiss, which, in places, shows a distinct "augen" texture. The proportion of mica, quartz, and feldspar in the pegmatites is quite variable. The feldspar varieties include orthoclase, microcline, and albite. A considerable number of accessory rare minerals have been found in the Amelia pegmatites, and some of them have been used for gems. More than a half dozen mines have been opened in the county, but the Pinchbeck and Schlegal mines are the only ones that have been worked for mica in recent years.

The mines owned by the Hanover Mica Company, near Hewlitt, in Hanover County, were the first mines worked for mica in Virginia. These were first worked from 1867 to 1870 by Barr, Johnson and Company, of Erie, Pennsylvania, with a production of more than 60,000 pounds of clipped stove mica. Regular mining has not been engaged in within recent years, although about 1,000 pounds of rough mica of excellent grade and clear white color were worked from the mines during the fall of 1907. Some of this was reported to be about 18 by 33 inches in size.

The Pittsburg Mica Company's mine at Ridgeway, Henry County, was developed by an open cut about 100 feet long and 40 feet deep, and much cross-cut work. The plant completed at the mine in 1907 was destroyed by fire in 1908, which greatly curtailed the production of mica by the company for that year.

The production of mica in Virginia during 1909 was 7,833 pounds of sheet mica and 75 tons of scrap, with a total valuation of \$4,600, and was obtained from three producers. There was no production of mica reported in 1910.

LIST OF MICA OPERATORS

OPERATOR	OFFICE	MINE
American Asbestos Co.....	Terre Haute, Ind.....	Bedford City
Cole, A. L.....	Chatham	Chatham
Corson, F. W.....	Waymart, Pa	Amelia
Corson Mica Co., Inc.....	E. Stroudsburg, Pa.....	Amelia
Hanover Mica Co.....	Hewlett	Hewlett
Henry Mica Corporation.....	Columbus, Ohio	Martinsville
Mecklenburg Mica & Mining Co.....	Petersburg	Petersburg
Otto Hill Mica Mines.....	Findlay, Ohio	Bedford City
Patterson, J. M.....	Washington, D. C.....	Amelia County
Pinchbeck Mica Mines	Chula	Amelia Courthouse
Roanoke Mica Mining Co.....	Francisco, N. C.....	Roanoke
Watton & Fontaine.....	Axton	Martinsville

FELDSPAR.

The feldspar group includes a number of mineral species which chemically are silicates of aluminum with varying amounts of lime, and the alkalies, potash and soda. Of the nine known species of feldspar only a few are of commercial value, the principal ones being the potash varieties, orthoclase and microcline, and the soda variety, albite. Orthoclase or microcline, or an intergrowth of these two, are the species most commonly used by potters in this country. The potash feldspars are frequently associated with small quantities of the soda feldspar, albite, which occurs either as separate crystals or intergrown with the orthoclase or microcline.

Commercial feldspar usually occurs associated with quartz and mica as coarse crystallizations in pegmatite dikes, cutting granites, gneisses, and crystalline schists. Pegmatites are rocks usually of extreme coarseness and of irregular texture and composition. Dikes of pegmatite containing feldspar as an important constituent are quite widely distributed throughout the Virginia Piedmont region, hardly a county within the region being without them. Notwithstanding the abundance of these dikes in the Virginia Piedmont province, many of which contain commercial feldspar, the attempts to mine the mineral are comparatively few, and as yet the production is small and variable. Feldspar has been mined in Amelia, Bedford, Hanover, Henry, and Prince Edward counties. In a majority of these counties feldspar has been mined with the associated mica of the pegmatites.

In order to avoid disclosing individual figures, the production of feldspar in Virginia for the years 1909 and 1910 is combined with that of another subject.

LIST OF FELDSPAR OPERATORS

OPERATOR	OFFICE	MINE
Bedford Spar Co.....	Roanoke	Bells
Dominion State Mines Corporation.....	Farmville	Prospect
Patterson, J. Murrell.....	Washington, D. C.....	Amelia County
Pinchbeck, W. L.....	Chula	Amelia
Schlegel	Jetersville	Jetersville

ASBESTOS.

Prior to 1907, Virginia was a producer of asbestos for a number of years. No production has been reported during the last four years. The mineral has been noted in a number of the Piedmont counties, and it has been mined in Amelia, Bedford, and Franklin, principally the two latter. The mines have been inactive since 1906 and the mill at Bedford City for fiberizing the asbestos is closed, though there is a probability that it will be in operation again in the near future.

In Bedford County, the mines of the American Asbestos Company are located near Chestnutfork post-office, about 12 miles south of Bedford City, on the Hubbard farms. According to Diller^a, the asbestos rock is of two types. The first type is like that of Sall Mountain, Georgia, and is composed essentially of fibrous amphibole, the fibers of which are arranged in groups or bundles lying in all directions, and is derived from pyroxenite. The other type is a peridotite composed chiefly of granular olivine, with numerous acicular crystals and fibrous bundles of anthophyllite. Diller^b states that this type is cut by a few small veins of cross-fiber anthophyllite, one-eighth to three-quarters of an inch in length. The fiber is flexible, somewhat elastic, has numerous cross fractures, and is relatively short and brittle. The asbestos mined occurs as vein-like masses of slip fiber, lying parallel to the plane of slipping, which cut the rock as occasional planes of shearing. These masses are very irregular, locally 18 inches thick, and along the strike have a length of about 30 feet.

In Franklin County, a small amount of asbestos was recently mined from a 40-foot shaft a short distance east of Rocky Mount. The asbestos-bearing rock^c is amphibolite, which locally contains some olivine, and is much altered to chlorite and serpentine. The asbestos is found in a vein which lies parallel to the schistosity of the inclosing amphibolite, with strike S. 50° E. and steep dip to the northeast. The principal constituent is probably tremolite.

^aDiller, J. S. Mineral Resources of the United States, Part II, Nonmetallic Products, 1907, p. 718.

^bIbid., pp. 718-719.

^cIbid., p. 719.

LIST OF ASBESTOS OPERATORS

OPERATOR	OFFICE	MINE
American Asbestos Co.....	Terre Haute, Ind.....	Chestnutfork
Heermance, E. Van Ness.....	New York, N. Y.....	Rocky Mount
Hubbard, L. F.....	Body Camp	Body Camp
Pine Mountain Mica & Asbestos Co.....	Richmond	
Smithers, W. C.....	Rocky Mount	Rocky Mount

TALC AND SOAPSTONE.

Virginia is by far the most important state in the United States in the production of soapstone, which has wide distribution over the Piedmont region. It has been noted in the following counties: Albemarle, Amelia, Amherst, Bedford, Buckingham, Campbell, Carroll, Charlotte, Fairfax, Floyd, Fluvanna, Franklin, Grayson, Henry, Louisa, Nelson, Patrick, and Stafford. Many of the deposits are of excellent grade, and the stone has been quarried on a commercial scale in at least six of the above-named counties; but practically the entire production in Virginia at present comes from the Nelson-Albemarle counties belt.

In Fluvanna and Buckingham counties, soapstone was quarried many years ago on a small scale near the mouth of Hardware Creek, and the product used locally for hearths, jambs, and other parts about chimneys. It has also been made use of further east in the southern part of Fluvanna County, at Bremono, and a good grade of it occurs at several localities in the vicinity of Palmyra.

In Albemarle County, a little west of Green Mountain, is a belt of soapstone associated with quartzites and micaceous schists, which is traced southwestward through Nelson into Campbell, Bedford, and Franklin counties. The belt widens in Nelson County and is associated with some serpentine. It passes thence as a narrow belt along the western base of Buffalo Ridge, in Amherst County, crossing the James River above Lynchburg, and is exposed about two miles west of the city on the road leading to Bedford City, and is exposed again two and a half miles west of New London in Bedford County. Continuing in the same direction, the stone is seen again at the meadows of Goose Creek, where it has been quarried to some extent. Continuing still further westward, it is exposed in several nearly parallel belts, of which the most eastern makes its appearance near Pig River in Franklin

County. A second belt occurs in the same vicinity near the eastern base of Jack's Mountain; a third still further west about one mile from Rocky Mount; and a fourth yet more to the west on the eastern slope of Grassy Hill. The stone has been quarried in a small way at several places in Franklin County, near Rocky Mount, and used strictly for local purposes. Extensive quarrying operations are in force in the Albemarle-Nelson counties' portion of the belt, which is described below.

In Amelia County, south of Chula, and about four miles from Amelia, soapstone of good quality was quarried quite extensively many years ago. A second more extensive area of soapstone of excellent quality occurs on the north side of Flat Creek, about four and a half miles north of Jetersville. On the headwaters of Walnut Creek, a tributary to Flat Creek, soapstone has been quarried to some extent. Quarrying was begun in 1904, and during the summer of 1906 numerous other smaller openings were made nearby. This property is controlled by the Tip Top Soapstone Company, and much preliminary work was in progress during 1908 preparatory to systematic quarrying in 1909.

In Louisa County, soapstone of good quality is reported to have been quarried near Oakland and Trevilians.

In Fairfax County, soapstone occurs two miles east of Annandale, one mile east of Tenley, and east of Falls Church. In each of these localities, the soapstone occurs as lenticular bodies closely associated with basic eruptive rocks, and were probably derived from peridotite and pyroxenite. All of these bodies have been worked to some extent, and in the Annandale area much stone has been quarried and sawed. The stone is of good quality, even-grained, and of uniform light bluish-green color, without seams and schistose planes developed in it. Small quarries of soapstone are operated in Fairfax County, near Clifton and Wiehle. At the former, soapstone is ground, but at Wiehle it is sold in the crude state just as it is taken from the quarry.

In Henry County, near Spencer's store, quarries of soapstone were opened some years ago. The material was of excellent quality, and blocks of any required dimensions were reported to have been

quarried. These were sawn out and then finished by planing. They were used in the foundations of houses and for other purposes.

In Albemarle and Nelson counties, the soapstone belt is a short distance west of Green Mountain, and, to the east, near and approximately parallel to, Hawkins, Finley, Ball, and Appleberry mountains. It has a general northeast-southwest direction, and is three to five miles southeast of the main line of the Southern Railway, which it roughly parallels. Quarries have been opened on the belt at numerous points for a distance of nearly 30 miles. Several of the most extensively worked quarries have reached depths of more than 120 feet. The larger quarries are well equipped with all necessary modern machinery for getting out the stone, including channeling machines for quarrying the rock, and at each quarry is a mill for sawing, dressing, rubbing, and polishing the stone, and other machines for grooving and drilling holes. The excellent quality of this stone adapts it to a wide range of uses, the principal ones including laundry tubs, sanitary purposes, electrical purposes, sinks, and cooking utensils.

In Stafford County, soapstone of good quality occurs near Garri-sonville.

The production of talc and soapstone in Virginia during 1909 showed a marked increase over that of 1908. The figures were 26,511 short tons, valued at \$523,942, as compared with 19,616 short tons, valued at \$458,252 in 1908, an increase in quantity of 6,895 tons, and in value of \$65,690, or 14.3 per cent. The 1909 production was obtained from 11 producers, operating in five counties, namely, Nelson, Fairfax, Albemarle, Amelia, and Campbell. Only a small proportion of the total quantity of talc and soapstone quarried in Virginia is sold in the crude state. The talc and soapstone production is classified in the following four groups: Rough or crude, sawed into slabs, manufactured articles, and ground.

The production of talc and soapstone in Virginia during 1910 amounted to 25,908 short tons, valued at \$510,781, as compared with 26,511 short tons, valued at \$523,942 in 1909. These figures represent a decrease in quantity of 603 tons, and in value of \$13,161, or 2.5 per cent. The 1910 production was obtained from 9 producers operating in four counties, as against 11 producers operating in five counties.

during 1909. Although there was a decline in the total production, practically half of the quarries operating increased in production. The 1910 production was from the four following counties: Albemarle, Campbell, Fairfax, and Nelson. Of the total production, 1,388 tons were sold as crude talc, and 2,502 tons were sold in the form of slabs. More than 82 per cent of the production was sold as manufactured products, chiefly as laundry tubs.

In the following table are given the quantity and value of talc and soapstone produced in Virginia during the years 1909 and 1910, according to the condition in which it was marketed.

Production of Talc and Soapstone in Virginia during 1909 and 1910, according to varieties.

	1909		1910	
	Quantity Short tons	Value	Quantity Short tons	Value
Rough Ground ^a }	2,150	\$ 9,450	2,108	\$ 8,364
Sawed into slabs.....	2,868	53,859	2,502	47,542
Manufactured articles ^b ..	21,493	460,633	21,298	454,875
Total	26,511	\$523,942	25,908	\$510,781

^aFor paint, paper filling, complexion powders, lubricants, etc.

^bIncludes washtubs, laboratory or kitchen sinks, stove bricks, griddles or other mill stock.

There is given in the table below the yearly production of talc and soapstone in Virginia from 1905 to 1910, inclusive:

Production of Talc and Soapstone in Virginia, 1905-1910, in short tons.

Year	Quantity	Value
1905.....	17,665	\$425,090
1906.....	23,624	590,800
1907.....	26,278	631,880
1908.....	19,616	458,252
1909.....	26,511	523,942
1910.....	25,908	510,781

LIST OF TALC AND SOAPSTONE OPERATORS

OPERATOR	OFFICE	QUARRY
Austin Run Mining Co.....	Philadelphia, Pa	Garrisonville
Bull Run Talc & Soapstone Co.....	Clifton Station	Clifton Station
Climax Soapstone Co.....	New York, N. Y., or Elmington Elmington	
Cuthbert Land & Development Co.....	Wiehle	Wiehle
Eureka Soapstone Co.....	Shipman	Shipman
Fairfax Soapstone Co.....	Wiehle	Wiehle
Gilmore, W. J.....	Louisa	Louisa
Hester Estate, B. H., W. S. Buchanan, Mgt.	Trevilians	Trevilians
Hutchinson, H. B.....	Washington, D. C.....	Shipman
National Soapstone Co.....	New York, N. Y.....	Wiehle
Old Dominion Soapstone Corporation.....	Esmont	Damon
Otter River Stone Co.....	Bramwell, W. Va.....	Lynch Station
Phoenix Soapstone Co.....	New York, N. Y.....	Arrington
Piedmont Soapstone Co.....	Boston, Mass	Asbestine
Pinkerton, W. A.....	Alberene	Alberene
Tip Top Soapstone Co.....	Philadelphia, Pa	Jetersville
Virginia Soapstone Co.....	Schuyler	Alberene and Schuyler

BARYTES.

Barytes has been mined for many years in various parts of the State. It occurs in many counties, but the industry has been confined to only a few of them. The counties in which it is found are: (1) those east of the Blue Ridge in the crystalline area, and include Amherst, Bedford, Buckingham, Campbell, Fauquier, Louisa, Nelson, Orange, and Prince William; and (2) those counties west of the Blue Ridge, and comprise Bland, Botetourt, Frederick, Montgomery, Rockbridge, Russell, Scott, Smyth, Tazewell, Warren, Washington, and Wythe. Of these, Bedford, Campbell, Pittsylvania, and Prince William counties, of the Piedmont province, and Russell, Smyth, and Tazewell counties, of the Mountain province, have practically yielded the entire production of the State.

Geologically, the barytes deposits found in the Piedmont region are associated either with the crystalline metamorphic rocks (limestone, chiefly) of probable Cambrian age, or with the Triassic red shale-sandstone series, and those of the Mountain region are usually associated with the Shenandoah limestone of Cambro-Ordovician age or its residual decay.

In the Triassic area of Prince William County, barytes mined about four miles south of east from Catlett is associated with red shale and impure limestone, usually filling fractures of variable width

in the red shale, and in thin, tabular, cleavable masses in the limestone. During 1908, deposits of barytes of good quality and in quantity are reported to have been opened in the vicinity of Bealton, Fauquier County.

In the crystalline area, the principal production of barytes has been from Campbell, Bedford, Louisa, and Pittsylvania counties. The Campbell-Pittsylvania counties area is traced for a distance of about 50 miles southwestward, beginning in the middle western portion of Campbell County, several miles east of Evington, and about 15 miles south of Lynchburg to three or more miles south of Sandy Level, in the northwestern part of Pittsylvania County. The most extensively worked deposits in this area are grouped about two centers, Evington, in Campbell County, at the northeast, and Toshes and Sandy Level, in Pittsylvania County, at the southwest extremity of the area.

The barytes in the extreme northwest corner of Pittsylvania County has been more extensively worked than in any other part of the belt. It has been developed by a large number of mines, grouped in two nearly parallel belts on either side of Pig River, just south of its entrance into Roanoke River.

Numerous openings have been made at different points on the belt between the two centers mentioned above, many of which have been extensively worked and have produced large quantities of excellent ore. The barytes occurs in the Campbell-Pittsylvania counties belt in intimate association with the crystalline limestone as irregular lenticular bodies or pockets, which measure from 100 to 200 feet or more, replacing the limestone. For the depths thus far attained in mining, there is immediately above and below the limestone, a variable thickness of a nearly black clayey mass, usually preserving the foliation of the original rock from which it was derived, and colored black from manganese oxide. Through this black clayey mass are usually distributed, in irregular fashion, lumps and nodules of barytes of large and small sizes.

Near Thaxton, in Bedford County, barytes occurs filling a fracture in a foliated granite of coarse grain. About three miles south of east from Lindsay, in Louisa County, barytes has been mined from a number of test pits and several shafts. The barytes occurs in pockets

having a thickness of about three feet where worked, and probably represents a filling of an irregular fracture in the crystalline schists.

In southwest Virginia, the barytes is found in association with the Shenandoah limestone or its residual decay. It fills in part, at least, fractures in the limestone, and in part it replaces the limestone. In the clay derived from the weathering of the limestone, the barytes is found in nodules of large and small size irregularly distributed through the clay.

The production of barytes for the years 1909 and 1910, respectively, can not be published separately without disclosing individual figures, hence it is combined with another subject. There were two active producers in Virginia in 1910, and the production of refined barytes was reported by one mill.

The following table gives the quantity, total value, and average price per ton of the barytes produced in Virginia from 1902 to 1908.

Production of Crude Barytes in Virginia, 1902-1908, in short tons.

Year	Quantity	Value	Average price per ton
1902	12,400	\$39,700	\$3.20
1903	5,700	20,400	3.58
1904	11,214	31,452	2.84
1905	6,468	27,838	4.30
1906	11,775	45,336	3.85
1907	9,254	32,833	3.55
1908	3,866	17,572	4.55
1909	(a)	(a)	
1910	(a)	(a)	

aCombined with another subject in order to conceal figures of production, there being only two producers during the years 1909 and 1910.

LIST OF BARYTES OPERATORS

OPERATOR	OFFICE	MINE
Berg, Henry	Verona, Pa.	Richland
Clinch Valley Barytes Co.	Honaker	Honaker
Langhorne, R. H.	Evington	Evington
Marks, S. B.	Leesville	Leesville
Nulsen, Klein & Krausse Manufacturing Co.	St. Louis, Mo.	Toshes
Pittsburg Baryta & Milling Corporation.	Pittsburg, Pa.	Russell and Tazewell counties
Williams & Son, John T.	Bristol, Tenn., or New York, N. Y.	Roanoke County (?)

GYPSUM.

Commercial deposits of gypsum in Virginia occur associated with salt in Washington and Smyth counties, in the valley of the North Fork of the Holston River. They are associated with rocks of Mississippian (Lower Carboniferous) age.¹ They are limited to the narrow belt on the northwest side of the Saltville fault, included between the fault and the Carboniferous shales and sandstones of the basal slopes of Pine and Little Brushy mountains. So far as has been made out, this narrow belt is composed of the Greenbriar limestone (Lower Carboniferous), and the beds of salt and gypsum.

Gypsum of excellent quality has been mined at numerous points in the Valley between Plasterco and within three miles west of Chat ham Hill. The mines of the United States Gypsum Company at Plasterco, Washington County, and the Southern Gypsum Company, three and a half miles northeast of Saltville, Smyth County, are the most extensive in the valley and were the only ones that produced in 1910. The production of gypsum in Virginia in 1909 is included under "Other products" in table on page 5, in order to avoid disclosing individual production, since there were only two producers. The 1910 production of gypsum is included under the same heading in table on page 6.

An underground examination of the gypsum, in the openings at Plasterco, indicates the occurrence of gypsum with much admixed anhydrite in huge boulder masses, in gray and red clays. Both clays are abundant, the red being softer than the gray and is utilized to some extent in the manufacture of plaster. The gypsum as mined is ground and calcined at the milling plant located at the mines, and the product is used chiefly as calcined and wall plasters, and as land plaster.

The Southern Gypsum Company began prospecting on its property, three and a half miles northeast of Saltville, in the summer of 1906. After nearly a year of drilling, the company demonstrated a large supply of gypsum and erected a mill with the capacity of 400 tons per day. The product of this company is put upon the market chiefly in the form of wall plaster and land plaster.

LIST OF GYPSUM OPERATORS

OPERATOR	OFFICE	MINE
Buchanan, D. J. & W. W.....	Chatham Hill	Chatham Hill
Southern Gypsum Co., Inc.....	North Holston	North Holston
U. S. Gypsum Co. ^a	Chicago	Plasterco

^aFormerly Buena Vista Plaster and Mining Co., Plasterco.

SALT.

Salt brines and rock salt occur in the Holston Valley of southwest Virginia in association with gypsum. The salt and gypsum deposits are confined to a narrow northeast-southwest valley of the North Fork of the Holston River, extending from Plasterco to within three miles of Chatham Hill, a distance of about 16 miles. The interbedded salt and gypsum shales with beds of rock salt and gypsum are regarded as of Mississippian (Lower Carboniferous) age.

A shaft was sunk in 1840 which struck a bed of rock salt at a depth of 210 feet. A large number of wells have been bored, ranging in depth from 300 to 1,400 feet, the greatest depth reached being 2,380 feet. The first borings for salt in this valley were in the old swampy lake-covered area near the present site of the town of Saltville. Mining of the rock salt has not been attempted, the entire salt product being derived from the salt brines of the wells. The entire salt industry at present is confined to the immediate vicinity of Saltville, and is controlled by the Mathieson Alkali Works.

In the early history of operations and, indeed, until within recent years, the product marketed was salt, which for many years amounted to between a half million and a million bushels of salt per year. The Mathieson Alkali Works stopped the making of salt in 1903, and from that time until 1908 the brines were utilized exclusively for the manufacture of sodium carbonate and caustic soda. The product was of superior merit from the start, and, because of this fact, a large and growing trade has been acquired. The manufacture of salt was again resumed in 1908 by the company, but, since there was only one operator, the figures of value of the production had to be combined with those of another subject, in order not to disclose private business. The same condition holds in respect to the production for the years 1909 and 1910, hence the figures are combined with those of another subject.

MINERAL PAINTS.

Ocher of more or less purity is found, and has been mined to some extent in each of the principal geologic divisions of the State, namely, the Coastal Plain, the Piedmont Plateau, and the Valley region. It has been mined at the following localities in Virginia: In the extreme eastern part of Chesterfield County, near Bermuda Hundred, on the Appomattox River; in the Little Catoclin Mountain, near Leesburg, in Loudoun County; near Bedford City, in Bedford County; near Keezletown, in Rockingham County; from the western base of the Southwest Massanutten Mountain, near Stanleyton, in Page County; and near Shenandoah Station, in Page and Rockingham counties.

In addition to these, ocher deposits are found rather widely distributed over the Valley and Piedmont provinces, and to some extent over the Coastal Plain, which have not been worked. In the Valley and Piedmont provinces, the ocher deposits are frequently associated with beds of iron ore. Deposits of ocher varying in color from red, yellow, and brown, and which seem particularly promising but not yet developed, are found in Campbell and Bedford counties; near Bon Air, in Chesterfield County; near Fairfield, in Rockbridge County; near Waynesboro, in Augusta County; and near Roaring Run, in Craig County. The production of ocher in Virginia during 1909 and 1910 is combined with another subject in order to avoid disclosing individual figures.

LIST OF MINERAL PAINT OPERATORS

OPERATOR	OFFICE	MINE
Bermuda Ocher Co.....	New York	Bermuda Hundred
Butterworth, R	Butterworth	Pride
Frazer Paint Co.....	Detroit, Mich	Bedford City
Stigleman, W. T.....	Snowville	Snowville
Virginia Ocher Corporation. ^a	Irwin, Pa	Stanleyton

^aFormerly Page Ocher Corporation, Stanleyton.

MARL.

Calcareous and greensand marls are widely distributed over the Coastal Plain or Tidewater region of Virginia. Calcareous marls are also found in places in the Valley region west of the Blue Ridge. They have not been developed in Virginia, however, except for local use.

The greensand marl is Eocene in age, and is formed chiefly along the inner margin or western portion of the Coastal Plain, where it is

exposed along the Potomac, Rappahannock, Pamunkey, and James rivers. It also occurs on the interstream areas, and has been traced southward from the James River almost to the State line. The green-sand marls contain a small percentage of potash and frequently phosphoric acid, the potash content varying according to the quantity of the mineral glauconite present. Shells are usually present in the deposits and supply lime in addition to potash and phosphoric acid. These marls have value as a fertilizer, and have been worked at a number of places on the James and Pamunkey rivers.

The calcareous (shell) marls are abundant over much of the Coastal Plain region, being especially so in the Miocene and, in places, hardly less abundant in the Eocene. The deposits are quite extensive in some localities, and contain as much as 80 to 97 per cent of calcium carbonate in places. In addition to their agricultural value, many of the beds are large enough and of sufficient quality to be used in the manufacture of Portland cement. The State Geological Survey has had under investigation these deposits with a view to their use in Portland cement manufacture, and a plant has been erected at Norfolk by the Norfolk Portland Cement Company for the manufacture of cement from these marls. Charters have been granted the Jamestown Portland Cement Corporation and the Colonial Portland Cement Corporation for the erection of plants and the manufacture of cement from marls and clays at Yorktown and near Grove Station. It is hardly necessary to call attention to the advantages afforded in this region to water transportation.

There was no production of marls in Virginia during the years 1909 and 1910.

PYRITE AND PYRRHOTITE.

The tabulation of production and value of pyrite in Virginia by years, given on page 111, includes both pyrite and pyrrhotite. Virginia has long held the position of first producer of pyrite among the pyrite-producing states in the United States.

Commercial pyrite occurs in Louisa, Stafford, Spottsylvania, and Prince William counties. Mines are opened in each of these counties, but the production has been from Louisa and Prince William counties. The pyrite mines in these two counties are probably the largest and

most extensively developed ones in the United States, and the product from them constitutes nearly 50 per cent of the total output of pyrite in the United States.

The pyrite mines in Louisa County were worked at different times for iron, copper, and pyrite. They were first opened and worked for iron in 1834, when the gossan overlying the pyrite for a depth of from 40 to 60 feet was mined for iron-making in the local furnaces. The Prince William County mine, near Dumfries, was first opened in 1889, but was not continuously operated until several years later.

The pyrite deposits in Louisa and Prince William counties occur as lenticular bodies, usually of large size, lying conformable or nearly so with the structure (foliation) of the inclosing rock. The lenses follow each other in the direction of strike, and may or may not be connected by thin and lean stringers of ore. The spacing between the ends of lenses is variable. In a few instances, partial overlap of the lenses has been observed. The lenses vary much in size, those in the Louisa County mines measuring several hundred feet long and as much as 60 to 80 feet in thickness.

As developed by the extensive mining operations, the ore-bodies are marked, in places, by rolls and swells and by pinching and narrowing. The inclosing rocks are metamorphic crystalline schists, chiefly micaceous, with more or less of the minerals, hornblende and garnet, developed in places. The normal rock is a mica-quartz schist, but mica schist without quartz, largely altered to chlorite, quartz-sericite schist, talcose and chloritic schists, and hornblendic schist, occur. Bands and stringers of more or less pure limestone are found in the walls near the ore bodies. Associated with these, is a considerable development of lime-bearing silicate minerals.

The ore consists of the massive-granular type, which varies in texture from very fine- to moderately coarse-grained. Some of it is very hard and non-friable, but much of it is quite friable, and in some mines practically all the ore is of the latter type. Much of the ore is admixed with white granular calcite and some quartz. Chalcopyrite, sphalerite, galenite, pyrrhotite, and magnetite are associated with the pyrite in small quantity. Chalcopyrite is present in sufficient quantity at some mines to warrant the saving of the copper from

time to time by precipitation of it from the mine water, when it is dried, screened, and barreled for market. Sufficient chalcopyrite is encountered in the Cabin Branch pyrite mine near Dumfries, in Prince William County, to warrant the building recently of a small smelter for the extraction of the copper.

The principal occurrence of pyrrhotite in Virginia is that of the "Great Gossan Lead" in Floyd, Carroll, and Grayson counties. This "lead" forms a well-defined vein of pyrrhotite varying in width up to 100 feet, and strikes southwestward from Floyd County, through Carroll into Grayson County, a distance of more than 20 miles. It is composed chiefly of pyrrhotite with admixed quartz and schist, and carries streaks and patches of chalcopyrite and pyrite. The vein fills a fault fracture in crystalline schists of unknown age, varies in width from a few feet up to 100 feet, shows a somewhat variable but average dip of about 45° , and has in general an approximate northeast trend. At present, pyrrhotite is mined by the Pulaski Mining Company near Monarat, Carroll County, and the ore treated at Pulaski for sulphur.

The total production of pyrite, including pyrrhotite, in Virginia during 1909, showed a decrease of 2,164 long tons, or 1.86 per cent, in quantity, and \$12,239, or 2.81 per cent, in value, in comparison with the figures for the previous year. The production in 1909 was 114,176 long tons, valued at \$423,283, as compared with 116,340 long tons, valued at \$435,522 in 1908. The average price per ton of pyrite in Virginia during 1909 was \$3.71, as compared with \$3.74 in 1908. The 1910 production of pyrite showed a considerable increase over the 1909 production, the figures for 1910 being 140,106 long tons, valued at \$525,437. It will be seen from these figures that there was an increase over the production for 1909, of 25,930 tons in quantity and \$102,154 in value. The average price per ton advanced from \$3.71 in 1909 to \$3.75 per ton in 1910.

There is given in the table below the production of pyrite in Virginia from 1904 to 1910, inclusive.

Production of Pyrite in Virginia, 1904-1910, in long tons.

Year	Quantity	Value	Average price per ton
1904	120,671	\$440,753	\$3.65
1905	123,183	426,008	3.46
1906	128,794	431,388	3.35
1907	124,740	372,586	2.99
1908	116,340	435,522	3.74
1909	114,176	423,283	3.71
1910	140,106	525,437	3.75

LIST OF PYRITE OPERATORS

OPERATOR	OFFICE	MINE
Arminius Chemical Co.....	Mineral	Mineral
Austin Run Mining Co.....	Philadelphia, Pa.....	Garrisonville
Braun, Johannes	Passaic, N. J.....	Green Bay
Cabin Branch Mining Co.....	Baltimore, Md	Dumfries
Hardy, W. N.....	Church Road	Iona
Louisa Mining Co.....	Cuckoo	Mineral (near)
Pulaski Mining Co.....	New York, N. Y.....	Monarat
Spottsylvania Sulphur Mines Co.....	Holladay	Holladay
Sulphur Mining & Railroad Co.....	Richmond	Mineral
U. S. Fidelity & Guaranty.....	Baltimore, Md	Mineral
Williams & Son, John T.....	Bristol, Va.-Tenn.....	Bonsacks

ARSENIC.

Virginia has not been a producer of arsenic for several years. In 1903, the United States Arsenic Mines Company, of Pittsburg, Pennsylvania, began the mining of arsenopyrite (mispickel) at Brinton, in Floyd County. An extensive plant, erected for refining the product, was started in 1904, with the monthly capacity increased after January, 1905, to 90 tons of pure white arsenic. Operations were temporarily abandoned several years ago, and owing to the low price of white arsenic the Floyd County mines did not operate in 1909 and 1910. A company was organized in 1910 to manufacture Paris green from the white arsenic made at the Floyd County arsenic mine, and a plant was established at Norfolk, Virginia.

The mines are located 14 miles southeast of Christiansburg, at Brinton, Floyd County. The ore is arsenopyrite, a double sulphide of arsenic and iron, associated with pyrite, and occurs in "veins"

(lenses) in quartz-sericite schist, which is closely associated with a variable biotite gneiss, but the relations of the two rock types to each other, and of the gneiss to the ore bodies, are unknown.

PHOSPHATE.

Three forms of phosphatic material occur in the State; namely, (1) the marls of the Coastal Plain region, (2) pebble phosphate west of the Blue Ridge near Clifton Forge, and (3) dikes of nelsonite—a rock composed normally of a mixture of the minerals ilmenite and apatite occurring in Nelson and Roanoke counties.

The shell and greensand marls of the Coastal Plain region frequently carry a small but variable percentage of phosphoric acid. These marls are not rich enough, however, in phosphoric acid to render them of commercial value as a source of phosphate.

West of the Blue Ridge, the occurrence of phosphatic nodules has been observed at the base of Devonian black shale, at Clifton Forge, but the extent of this material is yet unknown.

The nelsonite dikes in Nelson County are numerous and extend over a considerable area. Much variation is shown in the mineral composition of the rock composing the dikes. Normally, the rock is a granular mixture of the minerals white apatite and black ilmenite in variable proportion. Either mineral may predominate over the other in quantity. Near Rose's Mill, the ilmenite of some of the dikes is largely or entirely replaced by rutile giving at times a rock composed essentially of apatite and rutile with little or no ilmenite. In the vicinity of Lovingston, some of the dikes are composed principally of magnetite and biotite with a variable amount of apatite, while others are made up almost entirely of apatite. Chemical analyses of the nelsonite, collected from dikes over different parts of the area, show the calcium phosphate to range as high as 33 per cent.

The occurrence of the rock nelsonite in this county has been known for many years, and it has been prospected in a small way by open pits, cuts, and shafts at a number of places, chiefly near Roseland, Bryant, Rose's Mill, and Lovingston. The development work in the nelsonite dikes, near Rose's Mill, by the General Electric Company, was for the mineral rutile and not for the phosphate mineral apatite.

The dikes of nelsonite in Nelson County represent the largest concentration of phosphatic material yet known in the State. These deposits have been studied and mapped in detail by the Virginia Geological Survey, and a bulletin setting forth the results at considerable length will shortly be published. Phosphatic tock, not unlike the nelsonite of Nelson County, occurs about four miles east of Roanoke, where considerable prospecting was done about seven years ago.

GRAPHITE.

Graphite is rather widely distributed through the Piedmont region, occurring chiefly in the schists and gneisses, but as yet no actual production of the mineral has been reported. The occurrence of graphite has been noted in the following counties: Albemarle, Amelia, Buckingham, Charlotte, Loudoun, Louisa, Nelson, Orange, and Powhatan.

Probably the most encouraging occurrence of the mineral is in the northern part of Albemarle County, between Free Union and Boonsville, near Buck Mountain. The graphite occurs here in irregular vein-like masses in gneisses and syenites and their residual decay. It is of good quality, and blocks weighing several hundred pounds are easily extracted. The Naylor-Bruce Graphite Company acquired the property several years ago and made some developments on it, but closed down within a short time without any production.

RUTILE (Titanium).

The only locality in the Atlantic States where rutile has been mined in quantity is in the Tye River-Hat Creek area of Nelson County. The area is a large one, located in the foot-hills region of the Blue Ridge, and is distant about 7 miles northwest of the main line of the Southern Railway. A second area of commercial rutile was discovered recently in Goochland and Hanover counties about 20 miles west and northwest of Richmond.

Two distinct types of rutile are mined in the Nelson County area. In the first type, designated pegmatite rutile, the rutile occurs chiefly as disseminated grains of variable size in an igneous rock of very coarse- to medium-grained crystallization of feldspars and blue

quartz with, in places, much hornblende. In the second type, designated nelsonite rutile, the rutile occurs in even-granular rocks, having dike-like characters, and composed normally of ilmenite and apatite. Near Rose's Mill, on Piney River, the ilmenite of the nelsonite is almost or entirely replaced at times by rutile, the rock ranging from an ilmenite-apatite mixture, in which little or no rutile is present, to a rutile-apatite mixture, containing but little ilmenite, with intermediate gradations in the ratio of ilmenite to rutile.

The American Rutile Company began mining the pegmatite rutile in 1901 from side-hill cuts along the east side of Tye River, a short distance below the entrance of Hat Creek, and, in 1902, a milling plant was built for concentrating the rutile. The rutile is very pure, of red to reddish brown color, and occurs chiefly as large and small grains, disseminated principally through the feldspar, but also in the blue quartz and the hornblende. The rutile is admixed in places with some ilmenite.

In 1907, the General Electrical Company began mining operations for rutile in the nelsonite dikes near Rose's Mill, about 7 miles northwest of Tye River post-office. After considerable prospecting had been done the rutile content of the dikes was found to be so irregular that work was abandoned in 1909. Hess reports that about 100 tons of rutile ore, carrying 50 per cent TiO_2 , were shipped which yielded 35 tons of concentrates. The nelsonite dikes in this locality carry large percentages of rutile in places—the dikes being composed almost entirely of rutile and apatite, the former predominating, but have been found to grade both laterally and vertically into the normal ilmenite-apatite rock.

The recently discovered (1909) deposits of rutile in the eastern portion of the Virginia Piedmont province, are grouped about several centers in the same general area in Goochland and Hanover counties. These are the Nuckols farm between Peers and Johnson's Springs and the Brown farm at Waldelock, Goochland County, and the Bowe farm on the north side of the South Anna River, near Gouldin, Hanover County. Some prospecting for rutile has been done on each of these farms. The country rock is a gneiss of variant composition, penetrated by pegmatite dikes that closely conform to the structure of the enclosing

gneiss. Both the enclosing gneiss and the pegmatites are usually deeply weathered. The pegmatite dikes show a somewhat marked foliated structure due probably to pressure effects chiefly. Rutile in very large quantity, ranging from fine grains to masses weighing several pounds, is scattered loose over the surface and in the soil. Masses of rutile weighing up to several hundreds pounds have been found on the Nuckols farm. More or less ilmenite is associated with the rutile and both occur as constituents of the pegmatite.

The rutile deposits of Virginia have been studied in detail by the Virginia Geological Survey, and a volume setting forth the results at considerable length will be published shortly.

According to Hess the total value of rutile concentrates produced in 1909 in the Nelson County area was estimated at \$10,000. The production of rutile in Virginia during 1910 was 556 short tons, valued at \$44,480.

LIST OF RUTILE (TITANIUM) OPERATORS

OPERATOR	OFFICE	MINE
American Rutile Co.....	Washington, D. C.....	Roseland
General Electric Co.....	Schenectady, N. Y.....	Rose's Mill
Myer, August	Richmond	Gouldin
Nuckols, A. C.....	Peers	Peers

MINERAL WATERS.

The mineral waters of Virginia are an important source of revenue in the State. Virginia has a very large number of spring resorts, and a great variety and abundance of well-known commercial waters. Virginia is second only to New York in the number of springs that are utilized commercially, and exceeds New York in the number of resorts.

All classes of mineral waters are found in the State, and some of these are among the most celebrated in the country. They are naturally divided into (1) those containing mineral salts in such proportion as to give them medicinal value, and (2) those approximately pure waters which are sold extensively for table or domestic use.

The production of mineral waters for 1909, exclusive of 83,254 gallons used in the manufacture of soft drinks, was 1,504,530 gallons, valued at \$203,455, these figures representing a decrease from the

production during the previous year, of 595,084 gallons in quantity, and \$3,660 in value. It will be observed that, while there was such a marked decrease in the quantity of mineral waters sold during 1909, the value lacked only \$3,660 of equalling that of the previous year. This is due to an increase in the average price per gallon of the water sold, the average price in 1909 being 14 cents per gallon as against 10 cents per gallon in 1908.

The production of mineral waters in Virginia during 1910 amounted to 2,441,923 gallons, valued at \$301,523. These figures, which are exclusive of 48,252 gallons used in the manufacture of soft drinks, represent an increase over the 1909 production, of 937,393 gallons in quantity, and \$98,068 in value. The average price per gallon of the water sold during 1910 was 12 cents.

The following table gives the production and value of mineral waters in Virginia from 1903 to 1910, inclusive.

Production and Value of Mineral Waters in Virginia, 1903 to 1910.

Year	Springs reporting sales	Quantity sold Gallons	Value
1903	41	2,561,502	\$ 477,410
1904	35	2,117,420	281,998
1905	37	2,340,287	589,102
1906	43	1,997,207	418,908
1907	44	2,442,075	431,770
1908	46	2,099,614 ^a	207,115
1909	49	1,504,530 ^a	203,455
1910	40	2,441,923 ^a	301,523

^aAmount used for soft drinks not included.

Of the \$203,455 worth of mineral waters sold in Virginia during 1909, \$102,296 worth was sold for medicinal purposes and \$101,159 worth for table or domestic use. The total number of springs reported as producing in 1909 was 49, as against 46 in 1908. These were distributed among the following 26 counties: Albemarle, Alexandria, Amelia, Augusta, Bath, Botetourt, Campbell, Chesterfield, Culpeper, Frederick, Henrico, Isle of Wight, Loudoun, Mecklenburg, Montgomery, Norfolk, Nottoway, Prince Edward, Roanoke, Rockbridge,

Rockingham, Surry, Sussex, Tazewell, Warwick, and Wythe. Several of the springs reported resorts, with total accommodations for 3,518 people, and eight reported bathing establishments.

Of the 1910 production of mineral waters, valued at \$301,523, \$153,633 worth was sold for medicinal purposes and \$147,890 worth for table or domestic use. The total number of springs reported as producing in 1910 was 40. These were distributed among the following 23 counties: Alexandria, Amelia, Augusta, Bath, Botetourt, Campbell, Chesterfield, Culpeper, Franklin, Frederick, Isle of Wight, Loudoun, Mecklenburg, Montgomery, Nottoway, Prince Edward, Roanoke, Rockbridge, Rockingham, Surry, Sussex, Tazewell and Wythe. Several of the springs (11) reported resorts, with total accommodations for 2,105 guests.

Out of a total of 63 mineral springs credited to Virginia, 40 reported sales during the year 1910. The list of springs follows, with those producing in 1910 marked by an asterisk (*).

*Alexandria Well, Alexandria, Alexandria County.

*Alleghany Spring, Alleghany Springs, Montgomery County.

*Basic Spring, Basic City, Augusta County.

*Bath Alum Springs, McClung, Bath County.

*Bear Lithia Spring, near Elkton, Rockingham County.

*Beaufont Spring, Beaufont, Chesterfield County.

*Bellfont Lithia Spring, Manchester, Chesterfield County.

Berry Hill Mineral Spring, near Elkwood, Culpeper County.

*Blue Ridge Springs, Blue Ridge Springs, Botetourt County.

Brugh's Spring, near Nace, Botetourt County.

*Buckhead Lithia Springs, Buckhead Springs, Chesterfield County.

*Buffalo Lithia Springs, Buffalo Lithia Springs, Mecklenburg County.

*Burnett's Mineral Spring, Hudson Mill, Culpeper County.

*Campfield Lithia Spring, Temples Station, Chesterfield County.

*Carper Lithia Springs, Radford, Montgomery County.

Como Lithia Spring, East Richmond, Henrico County.

*Coppahaunk Lithia Springs, Waverly, Sussex County.

*Crockett Arsenic Lithia Spring, Crockett Springs, Montgomery County.

- *Days Point Artesian Lithia Spring, Smithfield, Isle of Wight County.
- Diamond Spring, Diamond Springs Station, Princess Anne County.
- *Erup Mineral Spring, Glencarlyn, Alexandria County.
- *Falling Springs, Falling Springs, Augusta County.
- Farmville Lithia Springs, Farmville, Prince Edward County.
- *Fonticello Lithia Spring, near Richmond, Chesterfield County.
- *Harris Anti-Dyspeptic Spring, Burkeville, Nottoway County.
- *Holly Lithia Springs, three miles east of Richmond, Chesterfield County.
- Houston Chlorated Spring, Houston, Halifax County.
- *Iron-Lithia Springs, Tiptop, Tazewell County.
- *Jeffress Lithia Silica Spring, Jeffress, Mecklenburg County.
- *Jordan White Sulphur Spring, Jordan Springs, Frederick County.
- *Kayser Lithia Springs, Staunton, Augusta County.
- *Lone Jack Spring, Lone Jack Station, Campbell County.
- Magee's Chlorinated Lithia Spring, Clarksville, Mecklenburg County.
- Manganese Sodium Iodide Spring, Hallsboro, Chesterfield County.
- Massanetta Spring, Harrisonburg, Rockingham County.
- *Mecklenburg Mineral Springs, Chase City, Mecklenburg County.
- Mulberry Island Spring, Mulberry Island, Warwick County.
(Name changed to Chloride Lithia Spring).
- *Nye Lithia Springs, Wytheville, Wythe County.
- O'Connell Lithia Spring, Stribling Springs, Augusta County.
- Otterburn Lithia Spring, Amelia, Amelia County.
- *Pæonian Springs, Pæonian Springs, Loudoun County.
- Pantops Mountain Spring, 3 miles east of Charlottesville, Albemarle County.
- Paradise Spring, Clifton Station, Fairfax County.
- *Pickett Spring, Worsham, Prince Edward County.
- Powhatan Spring, Ballston, Alexandria County.
- Roanoke Lithia Spring, two and one-half miles west of Roanoke, Roanoke County.
- *Rockbridge Alum Springs, Rockbridge Alum Springs, Rockbridge County.

- *Rocky Mount Lithia-Magnesian Spring, Rocky Mount, Franklin County.
- *Rubino Healing Springs, Rubino Healing Springs, Bath County.
- *Seawright Magnesian Lithia Spring, Staunton, Augusta County.
Shenandoah Alum Springs, Shenandoah Alum Springs, Shenandoah County.
- Smithfield Artesian Well, Smithfield, Isle of Wight County.
- *Stribling Springs, near Mount Solon, Augusta County.
- *Tripho-Lithia Spring, Claremont, Surry County.
Trois Fontaine Lithia Spring, South Hill, Mecklenburg County.
- *Virginia Etna Springs, Vinton, Roanoke County.
Virginia Lithia Springs, Osceola, Chesterfield County.
- *Virginia Magnesian Alkaline Spring, near Staunton, Augusta County.
Virginia White Rock Springs, Mount Solon, Augusta County.
- *Wallawhatoola Springs, near Millboro Spring, Bath County.
Waterlick White Sulphur Spring, Waterlick, Warren County.
White Oak Mineral Spring, Norfolk, Norfolk County.
- *Wyrick Mineral Spring, near Wytheville, Wythe County.

PRECIOUS STONES.

A variety of minerals of gem grade has been found in the crystalline rocks of the Piedmont province of Virginia. Some counties in this area, which seemingly offer good possibilities for the occurrence of gem material, have not yet been exploited for this purpose. The known counties which have either produced gem materials, or contain minerals which might be of desirable gem grade, are Amelia, Amherst, Bedford, Buckingham, Fairfax, Hanover, Nelson, and Spottsylvania. Of these, Amelia County is the best known and has produced the largest variety and quantity of gem material. This material has come from the mica mines opened in the pegmatite dikes near Amelia Courthouse.

Those minerals known to occur in Virginia which have been used, or are probably capable of being used, for gem material are quartz including several varieties, garnet including several varieties, allanite, kyanite, fluorite (chlorophane), feldspar including several species, microlite, apatite, beryl, turquoise, columbite, and helvite. Although

these minerals occur in Virginia not all of them have been found to be of gem grade.

The value of the production of precious stones in Virginia for 1909 was \$2,500. There was no reported production of precious stones in Virginia during the year 1910.

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VIRGINIA GEOLOGICAL SURVEY

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THOMAS LEONARD WATSON, PH. D.
DIRECTOR

Bulletin No. VII

**Geology of the Gold Belt in
the James River Basin
Virginia**

By STEPHEN TABER
Assistant Geologist

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ASSISTANT GEOLOGIST

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LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, 1913.

*To His Excellency, Hon. Wm. Hodges Mann, Governor of
Virginia, and Chairman of the State Geological Commission.*

Sir:—I have the honor to transmit herewith for publication as Bulletin No. VII of the Virginia Geological Survey Series of Reports, a report entitled "Geology of the Gold Belt in the James River Basin, Virginia," by Dr. Stephen Taber, Assistant Geologist on the Virginia Geological Survey.

This report is the first of a series planned by the State Survey to cover the geology of the entire gold belt in Virginia, and it should prove of much value to those seeking information on the gold deposits of the area mapped and studied, including the counties of Buckingham, Cumberland, Fluvanna, and Goochland.

Respectfully submitted,

THOMAS L. WATSON,

Director.

GEOLOGY OF THE GOLD BELT IN THE JAMES RIVER BASIN, VIRGINIA

BY STEPHEN TABER.

INTRODUCTION

This report is a geologic and economic investigation of the Gold Belt in the James River Basin, Virginia, an area comprising 700 square miles in Fluvanna, Goochland, Buckingham, Cumberland, Powhatan, and Amelia counties. The occurrence and origin of the gold, copper, and sulphide deposits within the area are discussed in detail. The commercial slates of the area, while of great economic importance, are only briefly mentioned in this report as they will be considered at length in Bulletin No. X, now in course of preparation by the Virginia Geological Survey.

The field studies which form the basis of this report were made by the writer during June, July, and August, 1910, and July and part of August, 1911.

No attempt has been made to evaluate individual mines or to determine whether they can be operated at a profit, as that is properly the work of the consulting mining engineer and geologist; but such basic problems as the origin and distribution of the ore deposits, and their probable variation in depth—problems which can not be solved by the examination of a single property, or without the expenditure of much time and effort—have been investigated as fully as conditions would permit.

Acknowledgments.—The writer desires to thank Dr. Thomas L. Watson, State Geologist, under whose supervision the work was done, for the privilege of studying the area, and for his valuable advice and kindly assistance in the preparation of this report. He also wishes to acknowledge the many kindnesses shown him by the different operators in the district, and by others who aided him in the field investigations.

The topographic map of the gold belt in the James River basin (Pl. I) is compiled from the Palmyra, Farmville, Buckingham, and Appomattox sheets of the United States Geological Survey, with corrections inserted by the writer. The traverse maps, used as a base for the detailed geologic work, were compiled chiefly from surveys made by the writer. Control for the detailed map of the gold belt on the north side of James River (Pl. II) was furnished by the United States Geological Survey and the Chesapeake and Ohio Railroad, and for the Arvonja-New Canton map (Fig. 2) by the Chesapeake and Ohio Railroad. Other acknowledgments are made in the body of the report.

CHAPTER I. GEOGRAPHY AND HISTORY.

LOCATION.

The district described in this report is situated a little east of the geographic center of the State, and lies on both sides of James River, about 60 miles above Richmond. It comprises the southeastern part of Fluvanna County, most of the western part of Goochland County, the northern three-fourths of Cumberland County, and adjacent portions of Buckingham, Powhatan, and Amelia counties, Virginia. The exact location is shown in the index map, fig. 1, and a large topographic and geologic map of the area is given on Pl. I, which will be found in the pocket at the back of the book.

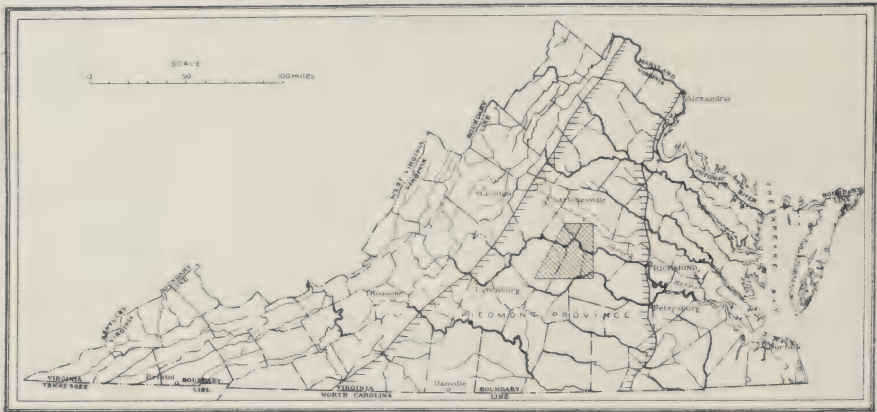


Fig. 1.—Index map showing location of area.

The area is trapezoidal in shape, being 30 miles long in a north and south direction, with a width of 15 miles at the northern end and over 32 miles along the southern boundary. It covers approximately 705 square miles.

The greater portion of the district is easily accessible from stations on the various railroads that cross it. The Chesapeake and Ohio Railway, following the north bank of James River, crosses the north central portion of the area in an east and west direction, while the Buckingham Branch of the Chesapeake and Ohio and the Virginia Air Line railways approxi-

mately parallel the western boundary, the former extending south from Bremo Bluff to Rosney, its terminus near the southern line, and the latter running from Strathmore northeast to Carysbrook and thence northward approximately parallel with Rivanna River. The Tidewater and Western Railway, a narrow gauge line, crosses the southeastern corner of the area.

With reference to the major physiographic divisions of the State, the area is located in the center of the Piedmont Plateau; it lies within the belt of old crystalline rocks that extends from New Brunswick to Alabama; and is a part of the gold belt in the Southern Appalachians region.

TOPOGRAPHY.

The topographic features of the gold belt present little by way of variation; the land surface is gently rolling, consisting of broad flat-topped hills or ridges and narrow valleys. The ridges are remarkably uniform in elevation, ranging from 450 feet above sea level along the eastern border of the area, to 550 or 600 feet in the western portion, and the valleys of the larger streams have an average elevation of about 225 feet.

The only variation in the monotony of the topography is furnished by Willis Mountain in the southwest corner of the area, which is the most prominent single feature of relief found in the State east of the outlying ranges of the Blue Ridge. It consists of a narrow ridge, about two miles long in a north and south direction, which rises abruptly from the Piedmont Plateau to a height of 1,159 feet above sea level, the upper portion being exceedingly precipitous and almost bare of vegetation.

DRAINAGE.

The area is drained by James River and its tributaries. James River flows directly across the area in a general easterly direction. Rivanna River and Byrd Creek are the principal streams entering James River on the north; and Slate River, Willis River, and Muddy Creek on the south. Appomattox River, flowing northeasterly, cuts across the southeast corner of the area and finally empties into the James below Richmond. Minor creeks and branches spread out from the principal streams, and completely drain all parts of the district.

The estimated mean yearly discharge of James River at Cartersville, where the drainage area is 6,232 square miles, is 8,189 cubic feet per second. These figures are based on daily observations taken between January 1, 1899, and December 30, 1905, under the direction of the Hydrographic Branch of the United States Geological Survey.^a During

^aGrover, N. C., and Bolster, R. H., Hydrography of Virginia, Bull. No. III, Geol. Survey of Virginia, 1906, pp. 142-152.

this period of seven years the maximum discharge for any single day was 97,800 cubic feet per second on December 15, 1901, and the minimum discharge for any single day 842 cubic feet per second on September 15, 1900.

SOIL.

The alluvial soils of the valleys, while limited in extent, are very rich; but the residual soils that cover the ridges are for the most part lean, and do not make first-class farming land. It was originally covered with a heavy growth of timber which has been greatly thinned out by cutting. All of the bottom lands and much of the uplands are at present under cultivation, but large areas of the latter have been allowed to grow up with a second growth of timber. While not naturally so rich as the bottom lands, much of this residual soil is capable, under proper farming methods, of a high degree of productivity.

CLIMATE.

The climate is equable and agreeable during the greater part of the year; the mean annual temperature is about 56° F., and the thermometer seldom drops as low as zero in the winter or reaches as high as 100° in the summer. The average yearly precipitation is about 42 inches, and this is quite evenly distributed throughout the year, so that prolonged droughts in summer or excessive rain and snow in winter are seldom experienced.

CULTURE.

The country is sparsely populated, and there are no large towns within the area. The chief industry of the inhabitants is farming, with corn and tobacco as the principal crops. Considerable lumbering is still carried on, and many railroad ties are shipped out of the district. Slate has been extensively quarried in Buckingham County for many years, and mining was at one time an important industry, but recently it has been carried on only in a spasmodic way. There are practically no manufacturing industries in this section, and although there is good water-power in certain localities it has as yet received little attention. Many of the smaller streams have been utilized to run saw mills and grist mills for local custom, but this is the extent of water-power development. Within the past few years great strides have been made in the public school system, and large new school buildings have been erected in nearly all of the towns.

HISTORY.

The early history of gold mining in the James River valley is so closely connected with the development of that industry elsewhere in Virginia, and indeed throughout the Southern Appalachians region, that a brief outline of the more important happenings in other parts of the gold belt will be given. The general history of the entire gold belt was summed up by J. D. Whitney^a in 1854, and by Geo. F. Becker^b in 1895.

According to Becker the first mention of gold in the Southern Appalachians states is by Herrera^c, and "is to the effect that on June 4, 1513, while Ponce de Leon lay near the southern end of the peninsula of Florida, he was informed that a cacique in the neighborhood had a quantity of gold." Several years later Spanish and French explorers refer to the possession of gold by the Indians; and Lemoyne, in his "Brevis Narratio"^d, of the journey made by Laudonnière in 1564, describes a method used by the Indians in separating gold from sands, which they found in rivers flowing from the Appalachian Mountains. Authorities differ as to how the Indians obtained their gold, but it seems probable that no systematic efforts were made by them to recover the metal. It can scarcely be doubted, however, that they found gold nuggets and made use of them, for in later years white miners found many large nuggets on the surface, some weighing several pounds, and such lumps must have been more plentiful before the country was settled. While the Spaniards are reported to have done some mining in Georgia in the seventeenth century, practically no systematic work was undertaken until after the beginning of the nineteenth century.

The earliest authentic reference to gold in Virginia is by Thomas Jefferson in 1782. He describes a lump of ore found on the north side of Rappahannock River about 4 miles below the falls. The gold "was interspersed in small specks through a lump of ore of about four pounds weight, which yielded seventeen pennyweight of gold of extraordinary ductility."^e

In 1799, the Reed nugget was discovered in Cabarrus County, North Carolina, and some years later more lumps were found, one weighing 28

^aThe Metallic Wealth of the United States, Philadelphia, 1854, pp. 114-134.

^bReconnaissance of the Gold Belt of the Southern Appalachians, 16th Ann. Rept. U. S. Geol. Survey, 1895, pt. III, pp. 253-258.

^cHerrera Dec. 1, Book IX, Chap. 5.

^dPublished by De Bry in 1591.

^eJefferson, Thomas, Notes on the State of Virginia, 2d Am. ed., Philadelphia, Nov. 12, 1794, p. 32.

pounds. Up to 1825 all the gold produced in North Carolina came from placer gravels, but during that year veins were opened in Montgomery County and afterwards in Mecklenburg County. Between the years 1804 and 1828, all gold of domestic production deposited at the United States mint, amounting to only \$116,000, came from North Carolina; but in 1829 the mint records show a production of \$2,500 from Virginia, and during the same year South Carolina sent gold worth \$3,500 to the mint.

In Virginia gold was discovered at very nearly the same time in both Orange and Goochland counties. Dr. Watson states that, "the Virginia Mining Company of New York, operating between the years 1831 and 1834, the Grasty tract of land in Orange County, was the first gold mining company incorporated in Virginia. The date of the incorporation was March 10, 1832. The Orange County, Virginia, deed books show that a one-half interest in a 20-year lease on the 5-acre mining tract, dated 1829, was purchased in 1831 for \$30,000 in cash."^a

The first discovery of gold in the James River basin was probably on the Collins place in Goochland County, about 1829. The first attempt at mining was by the Fishers, who built dams across the branch and prepared to work the gravels in rockers. Before active mining had actually begun, the property was turned over to Stevens Collins, who continued to work the placers for several years, and the Fishers transferred their operations to Busby Branch, 1.5 miles southwest of Tabscott. The discovery of the gold-bearing veins at the Tellurium mine is said to have been made in 1832 by G. W. Fisher while hunting, and according to J. R. Hamilton, veins were found on the Waller property by John Moss during the same year. Discoveries on other properties in the district followed in rapid succession. When Prof. W. B. Rogers wrote his "Report of the Geological Reconnaissance of the State of Virginia, 1835," Booker's mine (the Morrow mine) was already under active development. The history of the different mines, so far as known, is given under the description of individual properties in Chapter V.

On most properties gold was found first in the branches, and as the placer gravels were frequently rich and could be worked by crude methods necessitating little or no capital, the deposits along the branches were rapidly exhausted. In most cases the mining was done by lessees, who paid a royalty of about 10 per cent. of the gold recovered. The first primitive washing was with the pan, but almost from the first rockers were used on the branch gravels. Long-toms were also used, and in a few

^aWatson, Thomas L., *Mineral Resources of Virginia*, Lynchburg, 1907, p. 549.

places hydraulic mining was carried on, but most of the branches had insufficient grade to permit the use of sluice-boxes.

The veins from which the placer gold was derived were frequently discovered in working up the branches, and as the placer gravels became exhausted, a close search was made for the primary deposits. When the veins were first found, many of them were worked in a very primitive fashion, the gold being recovered by the crudest mechanical processes. The high percentage of free gold, the great depth of residual decay, and the low cost of mining these ores, helped to make such methods profitable. Small shafts or pits were sunk on the outcrops where pannings of the surface soil indicated the presence of much gold. In the decomposed rock above water level blasting was not necessary, and in some places it was possible to sink nearly 100 feet through "picking ground." The ore was usually raised by hand or sometimes with a horse-whim.

At first the ore was crushed by hand in iron mortars after a preliminary hand sorting, and the gold obtained by panning, mercury being sometimes used to amalgamate the gold. Crushing was also carried on in wooden mortars lined with iron, while the heavy pestles were attached to long sweeps operated by hand. At the Tellurium mine an arrastra driven by horse-power is said to have been employed for a short time, but was soon replaced by a stamp mill, or "pounding mill" as they were then called. According to Nitze and Wilkins this stamp mill was in operation as early as 1836, making it one of the first, if not the first, to be erected in this country. It had six wooden stamps, shod with iron, which weighed about 50 pounds each, and the ore was crushed on an iron die plate. The stamp stems were square and did not revolve as in later mills, for the cams worked in slots cut into the stems.

At a later date larger and more efficient mills were installed, a 40-stamp mill being built by Commodore Stockton at the Tellurium mine as early as 1848, while a mill with 72 stamps was in operation at the Morrow mine, Buckingham County, in 1854. Tremain steam stamps, various types of rotary pulverizers, and a number of other mills have been tried with more or less success at different mines.

As the water level was reached the rock became harder, rendering blasting necessary, the water that was encountered had to be removed by pumping, and the sulphides, which began to replace the oxidized ores found at the surface, contained less free gold. It is also probable that the total gold content of the surface ores was higher than that of the sulphide ores, because of some enrichment through concentration of a part of the

gold originally present in the eroded portions of the veins. All of these factors combined to make mining more expensive and the recovery of the gold more difficult, forcing most of the mines to cease operation after the ores above water level had been exhausted. This period in the development of many of the mines was approximately coincident with the outbreak of the Civil War, which put a stop to practically all mining operations both in Virginia and in the South generally.

Since the close of the war there have been spasmodic attempts to reopen many of the mines, and while these efforts have been accompanied by varying degrees of success and failure, they have for various reasons always ended in the same way—the final cessation of all mining. Gold can be recovered from refractory sulphide ores, but the methods of extraction are more complex and costly than the simple amalgamation processes that suffice for the oxidized ores near the surface. In the case of a producing mine, the introduction of auxiliary processes for the treatment of refractory ores necessitates an additional outlay of capital; but the metallurgical process now used had not been perfected when the exhaustion of free milling ores made the profitable handling of sulphide ores a necessity, if the mines were to remain open. It is much more costly to introduce new processes at old mines that have been long abandoned, for with the ores near the surface exhausted, prospecting is more difficult, and a larger amount of dead work must be carried out before pay ore can be developed. Most companies that have undertaken to reopen Virginia gold mines have done so with insufficient capital, and usually the men in charge of operations have lacked technical training. Mismanagement and ignorance of the common principles of mining have resulted in the erection of expensive surface plants before the mines were developed to a point that would permit the making of adequate tests of the quality and probable quantity of the ore.

The metallurgical processes which have elsewhere proved successful in recovering gold values from refractory ores, have usually included concentration of the sulphides, and separate treatment of the concentrates and tailings. The concentrates are generally smelted with other ores, or treated by chlorination or cyanidation after a preliminary roasting, while the tailings are usually subjected to some variation of the cyanide process. In 1879, a Mears chlorination plant was erected at the Phoenix mine in North Carolina, under the management of Mr. A. Thies, who improved and developed it into what was later known as the Thies process. In 1881, the Mears process is reported to have been tried at the Snead mine, but no details are given. An attempt to treat the sulphides at the Morrow mine by the Mears chlorination process, in 1893-94, is said to have failed

because of mechanical defects in the process used, though a satisfactory extraction of the gold was obtained.

According to Nitze and Wilkins a cyanide plant was in operation at the Gilmer (Young American) mine in 1893; with what success is not known. A preliminary test of the cyanide process, at the Bertha and Edith mine in 1897, is reported to have been successful, but the plant was destroyed by fire soon after completion and was not rebuilt. At the Hughes mine both concentrates and tailings were treated by the cyanide process, the sulphides being first roasted in a muffle furnace, and an extraction of over 90 per cent. is claimed.

Recently there has been renewed activity in the district, a number of the old mines have been reopened, and some new development work done, but as yet none of the mines have gone much deeper than 100 feet below the surface. As the free milling ores above water level are now practically exhausted, future mining necessarily depends on the successful treatment of sulphide ores.

PRODUCTION.

The statistics of production during the years when gold mining was most active in Virginia, are not sufficiently detailed to make possible the compilation of data giving the production of individual mines, or of the district as a whole. The few figures that are available relate to particular mines, and are given under the descriptions of the different properties in Chapter V. The annual production of gold in the James River basin has probably varied with that of the State. After the first deposit of \$2,500 at the United States mint in 1829, the gold production of Virginia steadily increased until 1833, when it reached a value of \$104,000. Thereafter it averaged about \$56,000 yearly up to the outbreak of the Civil War, and since the war the production has ranged from a minimum of \$2,024 in 1884, to a maximum of \$15,000 in 1906, averaging about \$6,000.

PREVIOUS GEOLOGIC WORK.

No detailed geological work dealing with this or any other portion of the gold belt in Virginia has been published previous to this report. Since the first discovery of gold, the mines in the James River basin have been examined from time to time by geologists and mining engineers, and a number of reports on individual properties have been published. Some of the early American and English geologists, who visited the district, became interested in the genesis of the ore-bodies and advanced theories to explain their mode of formation; but at that time the petrographic microscope had not been developed, and the science of geology had not reached a stage permitting detailed geological study in an area of old

metamorphic rocks. In more recent years the lack of accurate topographic maps, the depth of residual decay, and the absence of deep mines, have combined to discourage geologists from undertaking work in the district.

Several studies treating of the gold belt in the Southern Appalachians region as a whole have been published, and in these the principal mines in the James River valley receive brief mention. A number of papers, usually brief in character and dealing chiefly with the economic and engineering phases of the properties, have appeared from time to time. In the Bibliography is given a list of the titles of all the principal papers which refer in any way to the gold veins in this district. A brief review of the more important conclusions developed by the different geologists that have worked in the area is outlined below.

The first geological work, of which there is any record, was done by Prof. Wm. B. Rogers, who in 1835 published his "Report of the Geological Reconnaissance of the State of Virginia." He mapped all of the rocks in the gold belt as primary, but states that the rocks lying to the west of the belt of gneiss "assume various intermediate characters, until at length the truly crystalline structure is lost, and numerous forms of slate of very peculiar and equivocal features make their appearance. At what precise points the rocks of unequivocally primary character terminate, future researches must ascertain."^a

In describing the veins, Rogers points out that while in the main they conform to the inclination of the enclosing strata, this correspondence is far from exact, and that in places the veins divide, and the separated portions reunite or send off other branches. From this he concludes:

"It would thus appear, that these numerous veins of quartz are not to be regarded as deposits coeval with the regularly stratified rocks among which they are found, since in that case their position and structure would exhibit a like degree of uniformity, but as matter which, subsequent to the production of the neighboring rocks, was forcibly injected between them by igneous agencies from beneath, rising in the directions of least resistance, and therefore, generally, though by no means uniformly, following the plains of stratification of the rocks through which they passed. Instead, therefore, of considering them as beds like the adjoining strata, as some writers have done, we would incline to class them among *veins of injection*, of which numerous instances occur in other parts of the globe. We are the more persuaded of the correctness of this view of their origin, from the consideration that throughout all the region in which the quartz veins are found, very peculiar modifications in the structure and composition of the surrounding rocks are invariably to be observed—modifications for which no adequate cause can be found in the other igneous rocks which occasionally occur."^b

^aRogers, Wm. B., A Reprint of the Geology of the Virginias, New York, 1884, p. 72.

^bIbid., pp. 75-77.

Prof. B. Silliman examined the Busby and Moss mines in 1836, and while in the district also visited the Tellurium mine. As a result of his observations he reached conclusions in regard to the nature of the veins which are at variance to those advanced by Prof. Rogers. He states that: "The auriferous or gold-bearing quartz of the gold region of Virginia (and, as far as I am informed, of the states farther south) forms, not strictly veins but rather beds or layers—in general not interfering with but conforming to the regular structure of the country."^a

Prof. Rogers, in his "Report of the Progress of the Geological Survey of the State of Virginia for the Year 1839," describes the Triassic area lying in Prince Edward, Cumberland, and Buckingham counties under the name of "middle secondary formations,"^b but maps the rest of the area embraced in the present report as "primary."

Prof. D. T. Ansted in 1854, after a careful study of the region, strongly opposed the theories of Rogers, both as to the genesis of the gold veins and in regard to the manner in which the Alleghanies were formed. Ansted points out the resemblance of many of the "so-called veins" to the quartzite exposed in the bluffs at New Canton and says: "It is not without importance that these hard sandstone bands pass into and alternate with quartz bands parallel to them, and that this quartz is hyaline, and has in all respects the aspect and general character of the auriferous veins of the adjacent districts."^c He further states that:

"There were perhaps originally a multitude of beds, consisting of such materials as are still accumulating every day upon the earth. These beds were altered more or less by chemical agency, but while some still retain clear marks of their mechanical origin, others have become so far crystalline that the new arrangement of particles obliterated the old. That the syenites, greenstones, and gneissic rocks, as well as the chloritic schists, hornblendic schists, pale and blue slates, and other well-marked mechanical rocks, were once alternating aqueous deposits, there is no doubt in my mind; and I also believe that the gold as well as the iron was originally disseminated through the whole, and has been since rearranged and collected into certain portions, whether veins or bands, by a process of segregation, which has also changed siliceous sands into the condition of alternating quartz bands."^d

^aSilliman, B., Remarks on Some of the Gold Mines, and on Parts of the Gold Region of Virginia, Founded on Personal Observations Made in the Months of August and September, 1836, *Amer. Jour. Sci. and Arts*, 1837, vol. xxxii, pp. 98-130.

^b*Ibid.*, pp. 322-323.

^cAnsted, D. T., The Alleghanies and the Gold District of Eastern Virginia, *Scenery, Science and Art*, London, 1854, Chap. 3, p. 287.

^dAnsted, D. T., *Op. cit.*, p. 292.

Ansted described the Waller, London and Virginia, and Morrow veins, all of which were exposed at the time of his visit, and his descriptions show that he was a remarkably careful and accurate observer.

Dr. H. Credner, during the latter part of 1865, made a detailed examination of the gold deposits of Virginia and North Carolina, and the portion of his report relating to Virginia mines, which was published in 1868-69, gives a comprehensive list of the gold-bearing properties in the James River basin. His conclusions in regard to the geology of the deposits are stated as follows:

"The slate belt is of the highest technical interest, on account of the variety and multitude of mineral deposits which it encloses. Mineralogically it is made up of soft micaceous slates, siliceous slates poor in mica, chloritic, talcose, and roofing slates. All these varieties have an immediate connection with the analogous slate formation of North Carolina, which has been named by Emmons the Taconic system. We are therefore justified in describing this Virginia slate zone as belonging to this pre-Silurian oldest fossiliferous system.

"Somewhat as the coal measures lie between carboniferous sandstones so between the layers of these slates lie parallel metalliferous intercalations, striking and dipping with the enclosing rocks and therefore not veins proper in a geological sense."^a

In 1885, I. C. Russell made a reconnoissance of the Triassic (Newark) area lying in Prince Edward, Cumberland, and Buckingham counties, determining the presence of a fault along its eastern boundary north of Farmville, and several north and south faults in the central portion of the area.^b

In 1892, N. H. Darton announced the discovery of fossils in the slate of the Arvonian quarries, and the identification of these fossils by Walcott placed the slates in the upper Ordovician (Cincinnatian).^c

In 1911, Thomas L. Watson and S. L. Powell correlated the Arvonian slate belt with the Quantico slate belt in Prince William, Stafford, and Spottsylvania counties, Virginia, and described the occurrence of tuffaceous beds and metamorphosed rhyolite interbedded with the slates in each district.^d

^aCredner, H., Report of Explorations on the Gold Fields of Virginia and North Carolina. *Amer. Jour. of Mining*, 1868, vol. vi, p. 361.

^bRussell, I. C., The Newark System, U. S. Geol. Survey, Bull. No. 85, 1892, pp. 88-89.

^cDarton, N. H., Fossils in the "Archæan" Rocks of Central Piedmont, Virginia. *Amer. Jour. Sci.*, 1892, vol. xlv, pp. 50-52.

^dWatson, Thomas L., and Powell, S. L., Fossil Evidence of the Age of the Virginia Piedmont Slates. *Amer. Jour. Sci.*, 1911, vol. xxxi, pp. 33-44.

CHAPTER II.

DESCRIPTIVE GEOLOGY AND PETROGRAPHY.

INTRODUCTION.

The results of the areal survey of the gold belt in the James River basin are shown on the geological maps, Pls. I and II, and figs. 2 and 17. Owing to the lack of sufficient exposures it is not possible to map all of the region in equal detail. Plate I is a topographic and geologic map of the entire area, on which only the principal formations are differentiated. The northwestern portion is occupied chiefly by pre-Cambrian schists, quartzites, and gneisses of sedimentary origin, and the southeastern portion, by more or less gneissic igneous rocks of the granite-diorite family. The northern end of the Farmville area of Triassic rocks crosses the southern boundary and occupies a small area between Ca Ira and Willis Mountain.

A narrow belt of Ordovician rocks extends in a southwesterly direction from a point on Long Island Creek, between Palmyra and Wilmington, nearly to Alpha in Buckingham County, a distance of about 22 miles. Its boundaries are shown on the smaller detailed maps but not on Pl. I. A large scale map of the entire slate belt will be published shortly in connection with a report on the slate deposits of Virginia, now in preparation by the State Geological Survey.

Most of the gold mines are situated in the northeastern portion of the district shown on Pl. I, and this section is given in greater detail on Pl. II. Figure 2 is a detailed geological map of the region around New Canton and Arvonja, Buckingham County, showing the distribution of the Ordovician rocks, and the relation of the New Canton copper mines to the contact between the pre-Cambrian schists and intrusive granite.

All of the rocks in the area mapped, except the Triassic sediments, have been extensively altered by regional dynamic metamorphism, the degree of alteration being most intense in the pre-Cambrian rocks. In the following detailed descriptions the rocks are divided into two classes, namely, those that are sedimentary in origin and those that are igneous in origin; and the subdivisions of the two classes are based, so far as possible, on relative age.

ROCKS SEDIMENTARY IN ORIGIN.

GENERAL CLASSIFICATION.

The rocks of sedimentary origin, described in this report, may be divided for purposes of mapping and description into three main groups—pre-Cambrian, Ordovician, and Triassic—which are separated from one another by great unconformities. These groups will be discussed in the order given, which is that of relative age.

The pre-Cambrian rocks are the oldest in the district and have been extensively altered by dynamic regional metamorphism and by the intrusion of large masses of igneous rocks. In many instances they have been so completely metamorphosed that it is difficult or impossible to discover the character of the original sediments. For the most part these rocks have a fairly uniform strike in a northeast and southwest direction, and dip toward the east at angles varying from 45 to 90 degrees.

The Ordovician sediments are next in age to the pre-Cambrian rocks, but are separated from them by a long time interval, and are much less metamorphosed. The beds of this formation have been extensively folded and faulted, and while they mostly dip at steep angles, there is not the same uniformity in this respect as in the older sediments; the dip of the Ordovician beds changes suddenly within short distances, while the pre-Cambrian rocks are nearly isoclinal in dip.

The Triassic sediments constitute the youngest formation of the area, unless the recent alluvium, deposited in the larger valleys, is taken into consideration. The Triassic rocks have not been subjected to the crustal movements which have metamorphosed the older rocks, and since they have never been deeply buried, they are only partly consolidated. The beds dip gently in various directions and have been only slightly disturbed by minor faulting.

PRE-CAMBRIAN.

General Statement.

In the absence of direct fossil evidence, the correlation of the rocks which have been mapped as pre-Cambrian must rest entirely on lithologic and structural grounds. It is known that the Proterozoic era in North America was brought to a close by great crustal movements, and wherever the rocks belonging to this period have been observed in the Piedmont region, they show the effects of intense dynamic metamorphism. The chief evidence of the pre-Cambrian age of the older rocks, in the area under consideration, is furnished by their relatively high degree of crystallinity

and extremely schistose structure as compared with the rocks a short distance to the west, which are believed to be Cambrian in age. (See Geological Map of Virginia.^a)

The great age of these rocks is also evidenced by the long period of time intervening between their formation and the deposition of the Arvonian slates, upper Ordovician (Cincinnatian) in age, which are the oldest rocks in the area known to be fossil-bearing. After the pre-Cambrian sediments were laid down, they underwent the profound changes which resulted in their metamorphism; they were intruded by great masses of igneous rocks; and finally, sufficient time elapsed for erosion to remove a large amount of overlying material, and expose the intrusive granite and other rocks of the anamorphic zone; and all of this happened prior to the deposition of the Ordovician sediments.

The subdivisions of the pre-Cambrian series in this district must be based, in the absence of fossils, entirely on lithologic grounds. It is not even possible to state definitely which beds were laid down first or which were laid down last. The rocks have all been extensively altered by regional metamorphism and are entirely crystalline, so that it is frequently difficult to determine their original character; and in some instances, especially in the vicinity of later intrusives, it is impossible to distinguish between those that are igneous and those that are sedimentary in origin. The principal rock types are quartzites, schists, and gneisses, varying in texture and mineral composition; and rocks occur that are intermediate between the more important varieties. In fact nearly all gradations exist between the different extremes in mineral composition.

Quartzite.

GENERAL CHARACTER AND DISTRIBUTION.

Quartzites are fine-grained, siliceous rocks, originally deposited as beds of sand and later firmly cemented through metamorphic agencies. Some of the pre-Cambrian quartzites in this area are very pure, consisting almost exclusively of quartz, but usually there is more or less mica and chlorite present in small flakes, and with increase of these minerals the rocks grade into mica schists. In places the quartzites are highly ferruginous, containing considerable percentages of hematite and magnetite, and at several localities the iron content is so high that the beds have been prospected for

^aWatson, Thomas L., Geological Map of Virginia, Virginia Geological Survey, 1911.

iron ore. The quartzites also contain variable but usually unimportant amounts of feldspar, small inclusions of zircon, ilmenite, and rutile needles; and near igneous contacts, such minerals as garnet, hornblende, sillimanite, and cyanite are occasionally present in the impure varieties.

Since they are strongly resistant to erosion, the quartzites commonly outcrop along the ridges, and in places where the larger streams cut through such ridges the valleys are narrower, being frequently enclosed by cliff-like bluffs, while rapids are present in the channels. The residual soils resulting from the disintegration of the quartzites are sandy and infertile.

Most of the quartzite beds are less than 20 feet in thickness but some of them measure over 200 feet. They are frequently lenticular in shape, pinching out along the strike and dip, though some of the more persistent beds can be traced for a distance of several miles. The quartzites are the most widely distributed of all the rocks in the pre-Cambrian series of altered sedimentaries, yet, owing to the high inclination of these beds they do not form extensive areal formations.

The beds of quartzite are commonly mistaken for quartz veins and much money has been wasted in sinking pits to prospect them for gold.

DETAILS OF OCCURRENCES.

Bremo Bluff.—The most prominent exposures of quartzite occur on either side of James River just above the railroad station at Bremo Bluff. Here within a distance of half a mile there are a number of beds, ranging up to 200 feet and over in thickness, which are interbedded with fine-grained schists, the strike of the formations being about N. 20° E., and the dip 80° to 90° east. The largest beds of quartzite outcrop near the Bremo bridge over James River, and in passing westward they become successively thinner and more impure until they entirely disappear.

Because of their great resistance to erosion the larger beds of quartzite form a ridge, having an elevation of about 150 feet above the floor of the valley; and where this ridge is cut through by the river, it terminates in abrupt cliffs (see Pl. III, figs. 2 and 3), and the valley is much narrower than it is a short distance above and below (see map, fig. 2). The ledges of quartzite outcrop in the bed of the river, causing the rapids shown in Pl. III, figs. 1 and 2. The piers supporting Bremo bridge are built on one of these outcrops.

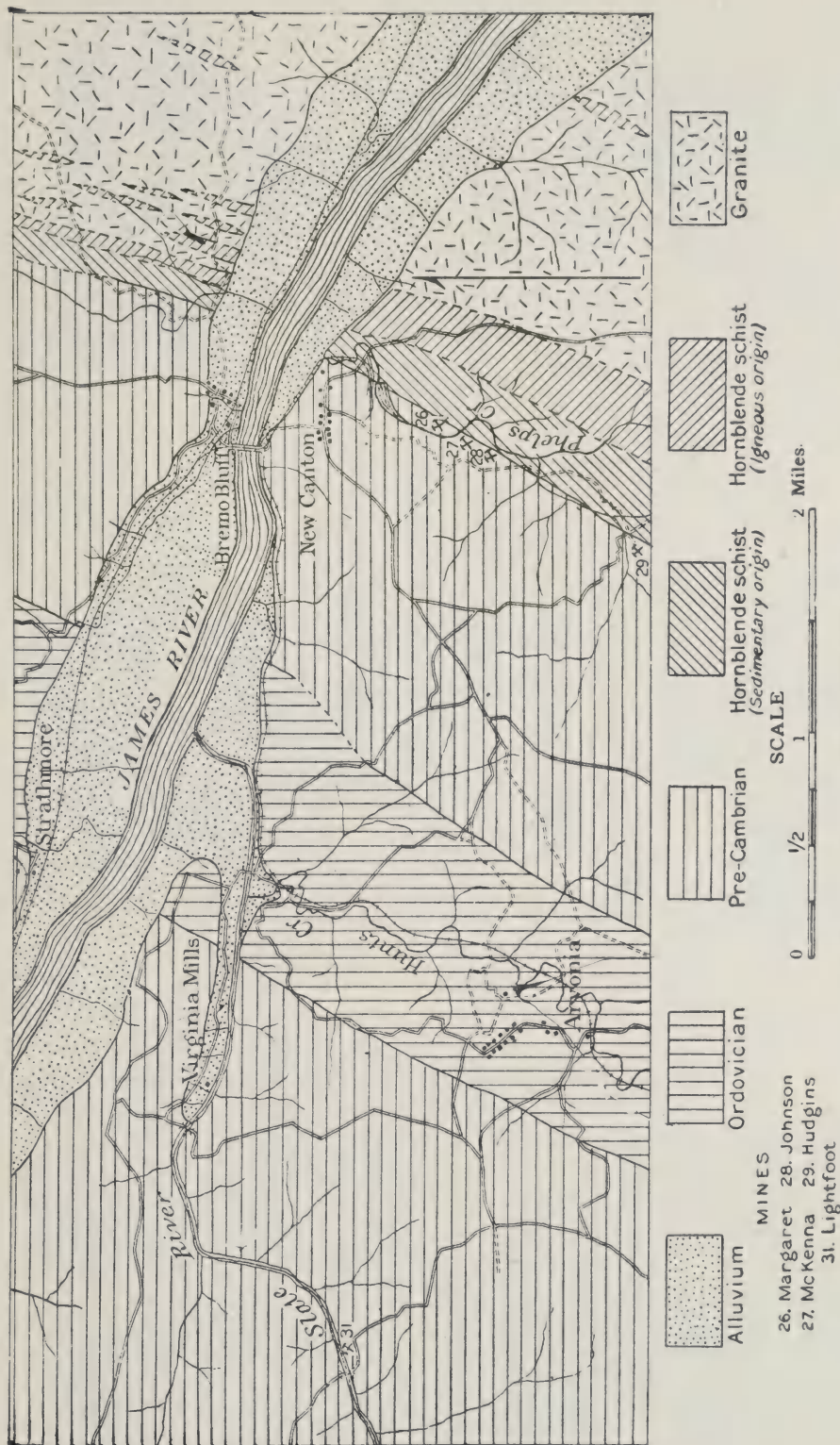


Fig. 2.—Geologic map of Arvonian-New Canton Area.

The quartzite is a fine-grained, close-textured rock, light gray in color when fresh, turning to light brown upon weathering, and where purest is nearly massive. The crustal movements, which have intensely metamorphosed the softer rocks with which they are interbedded, have scarcely affected the quartzites. Close inspection, however, shows a slight schistosity parallel to the bedding, and this becomes more conspicuous where the rocks are less pure. Fine flakes of sericite, chlorite, and biotite, and more rarely a little magnetite, pyrite, and garnet are the principal mineral impurities that may be detected megascopically.

In places the quartzites contain numerous small angular cavities arranged in bands or zones parallel to the bedding, and some of these are filled with calcite. The shape and distribution of these holes suggests that they may be due to fossils, possibly brachiopods, but if so they are so badly distorted as to make identification impossible. Quartz veinlets, averaging less than an inch in thickness, occasionally cut the quartzite, and some of the veinlets contain calcite.

Examined in thin sections under the microscope, the quartzite (Spec. 452)^a consists chiefly of small grains of quartz, nearly uniform in size, which fit closely together as in a mosaic. Dust-like inclusions are plentiful, especially near the border portions of the grains. The quartzite has evidently undergone considerable recrystallization, with possibly some enlargement of the original grains by the addition of quartz in parallel orientation; and the border inclusions probably represent iron oxide and other interstitial material which has become incorporated in the enlarged grains. Garnet occurs in small, irregular grains which are much fractured and partly altered to chlorite. Numerous small flakes of sericite are present, probably derived chiefly from argillaceous material, and there is also a little plagioclase and orthoclase feldspar, some of which shows partial alteration to sericite. Chlorite occurs in small, dark green flakes, and other minor accessories are biotite, light brown to green in color, a few small grains of magnetite and pyrite, and minute, colorless inclusions of zircon. The quartz shows very little optical distortion, possibly because of the extensive recrystallization.

Tellurium mine.—The so-called "Big Sandstone" vein, at the Tellurium mine, is a bed of quartzite cut by gold-bearing veinlets and slightly mineralized by the vein-forming solutions. This bed of quartzite varies up to 6 feet or more in thickness and can be traced for a distance of 3

^aThe numbers placed in parenthesis refer to field specimens and microscopic thin-sections, which are on file at the office of the Virginia Geological Survey.



Fig. 1.—Looking up James River from Brems bridge. Rapids due to quartzite beds.



Fig. 2.—Quartzite cliffs near north end of bridge. Looking northeast.



Fig. 3.—Nearer view of quartzite cliffs on north side of James River. Brems Bluff.

miles or more along its line of strike. The rock is white to light gray in color, when fresh, with a slightly pinkish tinge on weathering. It is quite free from impurities other than sericite, which is the only accessory mineral that can be distinguished with the naked eye. For a detailed microscopic description of this rock see pages 161-163.

London and Virginia mine.—At the London and Virginia mine there is a similar bed of quartzite, which in places is heavily impregnated with pyrite and more or less gold. This bed of quartzite ranges up to 20 feet or more in thickness, and the series of outcrops and prospect pits located along its line of strike indicate that it is practically continuous for a distance of 10 or 12 miles. Specimens of this quartzite from the London and Virginia and the Bondurant mines are described on pages 189 and 193-194, respectively.

Ferruginous Quartzite.

GENERAL CHARACTER AND DISTRIBUTION.

The ferruginous quartzites consist essentially of quartz, hematite, and magnetite. These three principal constituents vary greatly in their relative proportions, but quartz is usually dominant, though locally the iron oxides may constitute 80 or 90 per cent. of the mass. Some of the iron-bearing quartzites contain a little sericite and biotite, and with the increase of these minerals the rocks pass into ferruginous schists.

The ferruginous quartzites are of more frequent occurrence than the pure quartzites, and are found interbedded with the other sedimentary rocks in almost every portion of the pre-Cambrian area.

DETAILS OF OCCURRENCES.

Webb tract.—On the Webb tract, about three-quarters of a mile southwest of Lantana, a bed of ferruginous quartzite has been prospected for iron, and is exposed in several surface pits that have been sunk. The bed is over 6 feet in thickness, has an approximate strike of N. 45° E., and dips southeast at an angle of about 25°. It is interbedded with arkosic-gneisses, quartz-sericite schists, and other beds of quartzite.

The rock is fine-grained, even-granular, and, when fresh, is brownish-gray in color, turning to dark brown or black on weathering. It is composed essentially of quartz, specular hematite, and magnetite, but a little sericite may sometimes be recognized with the aid of a lens. It is slightly gneissic in structure, because of some recrystallization, accompanied by a partial segregation of the quartz and iron ores into narrow bands parallel

to the bedding and schistosity. The magnetite in these segregated bands or layers, which are usually 3 mm. or less in thickness, is somewhat coarser than that in the rest of the rock.

The quartzite is cut by numerous irregular quartz stringers, ranging up to 3 or 4 inches in width, and, for the most part, conforming to the strike of the enclosing rock. These quartz veinlets in places contain plates of micaceous hematite. Near the veinlets the quartzite seems to have been leached of some of its iron content.

Examined in thin section (Spec. 95) under the microscope, the quartzite shows a slightly schistose structure due to the partial arrangement of the iron ores in parallel lines. The quartz grains average about 0.25 mm. in diameter, and fit closely together, interlocking almost perfectly, but there is no evidence of granulation or optical distortion. The quartz individuals contain numerous small, dark red crystals of martite, the isometric form of hematite, which usually occur in well-formed octahedrons and are probably secondary (pseudomorphous) after magnetite. The larger masses of iron oxide are present between the quartz grains, and are frequently arranged in irregular, broken lines. Occasional hexagonal outlines show that a large proportion of the oxide is hematite, but much magnetite is also present. The fact that the quartz individuals in immediate contact with these larger masses of iron ore are practically free from the small inclusions, indicates that both the quartz and the iron ores have undergone recrystallization, accompanied by a partial segregation of the latter into larger masses. In places the iron ores are partly altered to limonite, and the boundaries between the quartz grains frequently show limonite staining. Considerable garnet (probably chiefly spessartite) is present, usually occurring as an interstitial filling between the quartz grains, and frequently along the contact between quartz and the iron ores. It is evidently secondary in origin, and, in some instances, appears to have partly replaced the quartz. The garnets are usually full of small dust-like inclusions, and more or less stained with limonite. Small, light green to colorless inclusions of zircon are common but not abundant.

The Ayre tract.—On the Ayre tract, 3.5 miles east of Dillwyn, a large bed of ferruginous quartzite has been extensively prospected for iron ore by several shafts and open cuts. One of the shafts is 40 or 50 feet deep, the others being somewhat less.

The quartzite outcrops boldly, in places standing 6 to 8 feet above the surrounding surface, and along most of its course follows the crest of a

ridge. The outcrops vary in width up to 200 feet or more, and the bed can be traced for over half a mile in a direction about N. 45° E.

The rock is essentially the same, both megascopically and microscopically, as that described above. Some of it is slightly coarser grained, and octahedral crystals of magnetite 0.5 mm. in diameter can be distinguished in hand specimens. Sericite is sparingly present.

Spessartite is occasionally present in the quartzite, occurring in irregular and more or less angular masses that range up to a foot or more in diameter. These masses are reddish-brown in color, with a waxy luster, and the weathered surface shows irregular, hackly cracks. Under the microscope (Spec. 420) the garnet is even-textured with few fractures and is seen to be full of extremely small inclusions. A few scattered grains of hematite are present, and with them there is often associated a little chlorite in fine, green shreds. The garnet is more or less stained by limonite.

The quartzite is cut by numerous stringers of vein quartz, frequently containing prisms of black tourmaline; and one specimen was found in which radiating clusters of tourmaline had penetrated the quartzite to a depth of about 0.5 cm. A large amount of tourmaline is present on the surface near the outcrops. A number of other occurrences of iron-bearing quartzite are reported southwest of this locality, in the vicinity of Willis Mountain.

The Scotia mine.—On the Scotia mining property, a bed of ferruginous quartzite, known as the Hodges vein, has been prospected for gold. The quartzite is cut by a number of small, gold-bearing veinlets, and has been slightly mineralized by the vein-forming solutions; otherwise it is identical with the other ferruginous quartzites of the district. The development work that has been carried out is sufficient to expose the marked lenticular shape of the deposit (see fig. 16, p. 171). A megascopic and microscopic description of the rock is given on pages 171-172.

Other localities.—Ferruginous quartzites occur at numerous other localities within the area mapped and thin sections from a number of them have been studied under the microscope, but as all of these are essentially the same, they will not be described in detail. At Cassell's mine 2 miles northeast of Caledonia a bed of iron-bearing quartzite 8 feet or more in thickness has been prospected by a surface pit. The rock exposed seems to have undergone greater recrystallization than most of the similar deposits in the area. It is described in detail on pages 174-175.

Ferruginous quartzite outcrops along the road three-quarters of a mile south of Stage Junction, where the bed has a strike of about N. 20° E.

Another occurrence is located on the road from Stage Junction to Pryors Crossroads, at a point three-quarters of a mile northeast of Big Byrd Creek. Outcrops also occur near the road between Palmyra and Wilmington, at Fork Union, and at several points in the vicinity of the Hughes mine. At the last-named locality some of the specimens have the appearance of hematite breccias recemented with magnetite and hematite.

Garnetiferous Quartzites.

GENERAL CHARACTER AND DISTRIBUTION.

Garnetiferous quartzites occur at several places in the district and are believed to be due to the metamorphic action of igneous intrusive rocks on impure quartzites. Chemical tests prove that the garnets are the iron-aluminum variety known as almandite. Sillimanite and sometimes a little cyanite are also present in association with the garnet. These rocks usually contain more or less hematite, magnetite, and sericite, and pass by gradation into the schists with which they are interbedded.

This type of rock has a limited distribution and was found only in the vicinity of contacts between the pre-Cambrian sediments and the intrusive granite.

DETAILS OF OCCURRENCES.

Lantana.—A bed of garnetiferous quartzite outcrops at Lantana, and for a mile southwest of the postoffice the road to Columbia follows approximately along the strike of this bed. It was traced in a northeast and southwest direction for a total distance of about 4 miles. The bed is probably not more than 10 or 15 feet thick and is usually much thinner.

The rock is banded in light and dark layers which range up to 2 or 3 inches in thickness. These layers are parallel to the bedding, the dark ones being composed largely of garnets while the light ones are chiefly of quartz. Radiating needles of sillimanite are common in places, and a little cyanite was identified. The garnets are dark red to brown in color, ranging up to about 0.5 cm. in diameter, but show very poor crystal form. Under the microscope (Spec. 96) they are seen to be full of small inclusions consisting of quartz and oxide of iron. These inclusions are elongated and arranged in lines approximately parallel to the bedding. The garnets are much fractured, and are stained by limonite which also coats many of the quartz grains. The quartz shows evidence of considerable optical distortion and of extensive recrystallization. Near the garnets the grains of quartz are sometimes arranged in bands that pass

around these crystals. There are a few flakes of sericite present, and the only other constituent noted was a soft white mineral that occurred as a coating and filled small cavities. It is probably some form of amorphous silica.

Weathered specimens of this rock often exhibit a hard surface crust having a rich reddish-brown color due to the presence of hematite, the iron of which has been leached from the partly decomposed minerals within, and reprecipitated near the surface.

The quartzite is interbedded with and grades into a fine-grained quartz-sericite schist.

Stage Junction.—A bed of garnetiferous quartzite outcrops in the road about half a mile northeast of Stage Junction. It is more schistose than the rock near Lantana, but is otherwise the same.

Hornblende-Bearing Quartzites.

Quartzites containing a few crystals of dark green hornblende occur at several localities close to the contact with the large area of intrusive granite, but they are of very limited distribution and therefore unimportant. The rocks placed in this classification are intermediate between the normal quartzites and the hornblende schists.

On the Columbia-Lantana road, three-quarters of a mile west of the bridge over Big Byrd Creek, there is an outcrop of hornblende-bearing quartzite. The rock contains blade-like crystals of hornblende, dark green to black in color, and ranging up to 3 mm. in diameter, which are embedded in an even-granular ground-mass of quartz with a few scattered crystals of garnet and sillimanite. A similar rock was found at the Margaret mine near New Canton (see p. 250).

A fine-grained quartzite containing scattered prismatic crystals of dark green hornblende is exposed on the east side of Randolph Creek, where it is crossed by the road running from Lawford to Gold Hill. A similar rock was noted near Hatcher Creek about 3 miles west of Hatcher.

Quartz-Sericite Schist.

GENERAL CHARACTER AND DISTRIBUTION.

Schists composed essentially of quartz and sericite in varying proportions are of common occurrence in all portions of the pre-Cambrian series of sedimentary rocks, and constitute one of the most important rock types of the area. In texture these schists range from fine to medium coarse-

grained, and in composition from sericite-bearing quartzites to rocks in which the mica is dominant. The finer grained varieties, containing much sericite, were described by the early geologists under the name of talcose schists. The coarser varieties, in which quartz is dominant, are very resistant to erosion and therefore frequently form the ridges and other higher elevations, outcropping with considerable prominence. The quartz-sericite schists pass by gradation into the sericite-bearing gneisses, cyanite schists, and the ferruginous as well as the pure quartzites. Nearly all the schists found in this region contain more or less sericite, and there are numerous rocks intermediate in mineral composition between the quartz-sericite schists and most of the principal varieties.

GENESIS.

The positive evidence of bedding and the gradation of the quartz-sericite schists into rocks, such as the quartzites, which are necessarily sedimentary in origin, leave no doubt as to the manner in which the schists were originally formed. The beds were probably laid down in shallow waters near the shore, partly in the form of quartz-feldspar sands and argillaceous sands, and partly in the form of finer sediments, possibly white clays. The present character of the rocks is due to their alteration under dynamic conditions in the zone of anamorphism, and certainly in some cases the change has been aided by the intrusion of the large granite magmas.

DETAILS OF OCCURRENCES.

Big Byrd Creek.—On the east bank of Big Byrd Creek, three-quarters of a mile south of Bowles' bridge, and $1\frac{1}{4}$ miles east of Stage Junction, there is an exposure of quartz-sericite schist in which the ratio of quartz to sericite is so great that it is almost a quartzite. The rock (Spec. 33) is fine-grained and white to light yellow in color when not stained pink and red by oxides of iron. It is highly laminated parallel to the schistosity, showing well-marked layers which are slightly folded and crumpled. The minerals distinguishable under the microscope are quartz, sericite, a little feldspar, and occasional inclusions of zircon. The quartz grains fit closely together and show little optical distortion. The feldspars are chiefly acid plagioclase and in places they show partial alteration to sericite. Most of the mica flakes are perfectly oriented parallel to the schistosity.

Lantana.—For a distance of 500 or 600 yards southeast of Lantana the road passes across a belt of quartz-sericite schist, and this belt may be traced

for 4 or 5 miles along its line of strike in a northeast and southwest direction, but in places it contains interbedded lenses of quartzite and other rocks. The schist (Spec. 42) is white to light gray in color, where not stained with iron, and usually fine-grained. Quartz is dominant over sericite, the flakes of which are all oriented parallel to the schistosity, so that when the rock is examined on surfaces at right angles to the cleavage it has the appearance of a quartzite rather than a schist. It is slightly banded, due to variation in the relative proportion of the quartz and sericite, and the layers show minor crumpling and folding.

A specimen (100) obtained from an outcrop $2\frac{1}{4}$ miles northeast of Lantana, upon examination in thin section under the microscope, shows a little orthoclase and acid plagioclase feldspar, and occasional fluid inclusions and rutile needles. The feldspars show partial alteration to sericite and are much kaolinized.

About a mile northeast of Lantana occurs a rock which is intermediate in composition between the quartz-sericite schists and the ferruginous quartzites. It is a fine-grained schist, bluish-gray in color, in which few of the minerals can be distinguished by the naked eye. In thin section (Spec. 89) under the microscope it is seen to consist essentially of quartz, hematite, and sericite, with a few scattered crystals of nearly colorless amphibole and possibly a little cyanite. The quartz grains are irregular in shape, fit closely together, and show some optical distortion. The hematite is chiefly of the micaceous variety.

New Canton-Dillwyn road.—There are numerous outcrops of quartz-sericite schist along the ridge road leading from New Canton to Dillwyn. This rock is slightly coarser grained than the schists previously described, and the schistosity usually has a crinkled or corrugated appearance. It is light greenish-gray to white in color, where not stained various shades of pink by iron oxides, and is composed essentially of quartz and white mica, with a small amount of light green chlorite, and occasional specks of specular hematite. It is very resistant to erosion and therefore outcrops prominently and forms the watershed between the streams flowing into Hunts Creek and Slate River, and those flowing into Phelps Creek and Willis River. Locally the schist is called *mountain rock*, because of its occurrence along the summits of the higher ridges.

A similar rock outcrops on Tower Hill, $2\frac{1}{2}$ miles south of Alpha and $3\frac{1}{2}$ miles east-northeast of Dillwyn, and also on the slopes of Willis Mountain.

London and Virginia mine.—A fine-grained quartz-sericite schist is exposed at the London and Virginia mine and at the other mines that

have been opened along the strike of the same vein. In this rock the percentage of sericite is high and is possibly dominant over the quartz. The schist, as well as the quartzite with which it is interbedded, has in places been heavily impregnated with pyrite. A detailed megascopic and microscopic description of the rock is given on page 186. A similar rock occurs in the mines near New Canton, and is especially prominent at the Hudgins mine (see p. 256).

Bondurant mine.—A quartz-sericite schist, which was found on the dump at the Bondurant mine, contains small lenticular eyes of light-blue opalescent quartz. This variety of the schist is similar to the hand specimen (211) obtained from the Scotia mine and described on page 170.

Other localities.—Quartz-sericite schist is present along the road 3 miles northwest of Ca Ira and parallels the contact with the granitic rocks on the east for a distance of several miles in a northeast and southwest direction. It occurs in the road 2 miles south of Kent's Store, and also a quarter of a mile northeast of Byrd Creek on the road between Stage Junction and Pryors Crossroads; it outcrops on Byrd Creek, $1\frac{1}{4}$ miles north of Grays Mill, and in the road three-quarters of a mile south of Carysbrook; and it was noted along the road $1\frac{1}{2}$ miles south of Gravel Hill. There are numerous other occurrences in the area, but these are sufficient to show the wide distribution of this rock type.

Cyanite Schists.

GENERAL CHARACTER AND DISTRIBUTION.

The cyanite schists are composed chiefly of quartz, cyanite, and sericite or muscovite, and the relative proportions of these constituents vary within wide limits. There are all gradation from a rock composed almost entirely of cyanite, to one composed chiefly of coarse-grained quartz with only scattered prisms of cyanite; and these schists pass by gradation into quartz-sericite schists in which cyanite is sparingly present or entirely absent. Cyanite is also present in some of the gneisses that have been intensely metamorphosed (see pp. 133 and 136-138).

The distribution of these schists is very limited and only two occurrences are known within the limits of the area mapped—one at Willis Mountain, and the other on the Trent farm, $3\frac{1}{2}$ miles southeast of Gravel Hill and 3 miles southwest of Hatcher. Similar schists have been described from the northwest corner of Charlotte County, about 25 miles southwest of Willis Mountain, and it is interesting to note that in each instance rutile is a prominent minor constituent.^a

^aWatson, Thomas L., and Watkins, J. H., Association of Rutile and Cyanite from a New Locality, Amer. Jour. Sci., 1911, vol. xxxii, pp. 195-201.

While cyanite is softer than most rock-forming minerals, it is almost unalterable, and therefore the cyanite schists are extremely resistant to the agents of decomposition, and outcrop boldly at each of the localities in this section.

GENESIS.

The structural relations of the cyanite schists, wherever observed, are indicative of a sedimentary origin, and, moreover, cyanite is not known to occur as a pyrogenetic mineral. The chemical composition of these schists, consisting chiefly of alumina and silica, suggests that they must have been derived from kaolin or very argillaceous sediments, and this view is supported by the unusually high titanium content. Van Hise has called attention to the concentration of titanium in shales and other fine-grained sedimentary rocks.^a The metamorphic minerals composing these schists were produced in the anamorphic zone under conditions of dynamic regional metamorphism, but the location of both occurrences, not far from large areas of intrusive granites, suggests that contact action may have been an influential factor in bringing about the alterations. Evidence in favor of the latter hypothesis is furnished by the variation in the character of the schist in the vicinity of a peculiar diorite dike, which occurs on the southern slope of Willis Mountain, and by the great abundance of tourmaline, chiefly in association with vein quartz, found near the base of the mountain. The absence of cyanite, sillimanite, and similar minerals from most of the contact rocks is probably due to the presence of iron, magnesium, and the alkalis, which have resulted in the formation of amphibole and mica rather than the pure aluminum silicates.

DETAILS OF OCCURRENCES.

Willis Mountain.—The topographical features of Willis Mountain are described on pages 89-91, the formation of the narrow ridge being attributed to the structural and lithologic character of the bed of cyanite schist which outcrops along the summit. This rock was described under the name of "kyanitic gneiss" by Rogers, who states that it "differs from all in its vicinity, and appears to have been elevated from below through the surrounding slates;"^b but the present writer saw nothing to indicate that faulting has been a factor in the formation of the mountain. The rocks

^aVan Hise, C. R., *A Treatise on Metamorphism*, Mono. xlvii, U. S. Geol. Survey, 1904, pp. 974-975.

^bRogers, W. B., *Geology of the Virginias*, 1884, pp. 314-315. (See also pp. 71-72 and 290-291.)

that constitute Willis Mountain offer greater resistance to erosion than any of the other rock types found in this region, and the gradual erosion of the softer rocks has left this ridge standing as a monadnock high above the level of the Piedmont peneplain. The rugged and cliff-like nature of the outcrops near the summit of the mountain is shown in Pl. IV, fig. 1.

The cyanite schist of Willis Mountain varies in texture according to the relative proportions of the two principal constituents—quartz and cyanite—and passes by gradation into the quartz-sericite schists with which it is interbedded. In places the rock is composed dominantly of cyanite, in large-bladed crystals, white to light gray or bluish-gray in color, and there are only minor amounts of quartz and sericite, the latter being sometimes practically absent; but elsewhere medium-grained saccharoidal quartz is predominant, with small prisms of cyanite scattered through the ground-mass. Rutile, occurring in small bright red grains disseminated indifferently through the other minerals, is the only remaining constituent which is ordinarily present, though tourmaline may occasionally be seen.

The cyanite crystals range up to 7 or 8 cm. in length, and on the weathered surface stand out in high relief. Under the microscope (Spec. 386) the mineral is colorless, frequently shows a slightly radiating texture, the cleavage is well developed, and occasionally there is a little alteration to sericite along the cleavage planes. Numerous irregular grains of rutile are present as inclusions, being usually arranged with their longer diameters parallel to the cleavage planes of the cyanite. The dominantly cyanitic variety of the schist has a noticeably high specific gravity.

On weathered surfaces the rock is often deep red to purple in color and much harder than at a distance of a few inches within the interior. This is due to the solution of the small amount of iron originally present, and its transportation by capillary attraction to the surface, where it is re-deposited by evaporation, partly in the form of limonite and partly as hematite.

On the southern slope of Willis Mountain, in the immediate vicinity of a diorite dike, the cyanite schist has been extensively altered with the production of new minerals, such as light brown biotite, nearly colorless chlorite, plagioclase feldspar, and calcite. The rock is heavily impregnated with pyrite, and about 40 years ago two shafts were sunk in this material in prospecting for copper. The rock is described in greater detail on page 114.

Trent farm.—On the Trent farm, $3\frac{1}{2}$ miles southeast of Gravel Hill and 3 miles southwest of Hatcher, there is a dike-like ledge of cyanite



Fig. 1.—Cyanite schists outcropping near summit of Willis Mountain.



Fig. 2.—Cyanite schists outcropping on the Trent farm.

OUTCROPS OF CYANITE SCHIST.

schist which outcrops for several hundred yards along the crest of a low ridge. It is 3 to 12 feet wide and in places stands 8 or 10 feet high, resembling a stone wall (see Pl. IV, fig. 2), and, indeed, it has been used as part of a fence to restrain cattle. This bed of schist has a strike of N. 10° E. and dips 30° to 40° E.

The rock is a heavy, compact schist, pink in color, and composed essentially of cyanite, quartz, and sericite. The cyanite occurs in flat-bladed prisms ranging up to 2 or 3 cm. in length, the quartz is medium-grained with a saccharoidal texture, and the sericite is present in small, glistening flakes. Examined under the microscope (Spec. 393), the cyanite is colorless, occasionally shows polysynthetic twinning, and in places is partly altered to sericite. Rutile is sparingly present in small grains, and a little titanite was noted in some of the quartz individuals. Fairly well formed zircons are also present as small inclusions in the quartz, and there is a little limonite, partly occurring as a stain on the other minerals.

The cyanite schist is interbedded with a medium-grained quartz-sericite schist (Spec. 394), white when fresh, and light brown to pink when stained with iron. Examined under the microscope, cyanite is seen to be present as a subordinate constituent and frequently shows multiple twinning with indefinite boundaries between the twins. Limonite is present as a stain along the contacts between the individual minerals, and also occurs in minute spherulites. A few inclusions of zircon are present in the quartz.

Knotted Schists.

GENERAL CHARACTER AND DISTRIBUTION.

Knotted schist is the name given to a series of fine-grained rocks, composed essentially of quartz, sericite, chlorite, and biotite, in which there are numerous pseudophenocrysts of garnet, biotite, carbonate, or pyrite—the latter minerals being of later formation than the schistosity of the rock. These large crystals were formed under mass static conditions, after the movements which produced the cleavage of the rock had ceased, for they show absolutely no parallelism in their orientation. They began to crystallize about favorable nuclei, and as they grew, the folia of the schist were gradually pushed aside, so that lenticular eyes or knots were formed, about which the enclosing folia are smoothly curved. The development of these minerals furnishes a very pretty illustration of the force exerted by growing crystals.

When the knotted schists are examined in thin sections under the microscope, it is seen that the minerals of the ground-mass have made room for the crystals of later growth partly by bending and partly by recrystallization. The micaceous minerals of the ground-mass are imperfectly arranged in thin layers or bands, which alternate with layers composed of quartz grains elongated parallel to the schistosity. Opposite the pseudophenocrysts, the layers of mica are pushed close together (see Pl. V, fig. 1, and fig. 21, p. 227), while the quartz which has been removed from these points has recrystallized in the ends of the lenticular eyes. In other words, the quartz has acted very much as ice does under pressure—it has gone into solution where the pressure was greatest and recrystallized where the pressure was least; and this transfer of material was undoubtedly brought about by the small amount of interstitial water present in the rock. In recrystallizing, the quartz grains have been partly arranged with their greater diameters oriented in directions pointing toward and away from the pseudophenocrysts, so that in thin sections cut parallel to the schistosity the quartz grains surrounding one of these larger crystals have a radiating texture (see Pl. V, fig. 2, and fig. 22, p. 228).

The particular kind of mineral present in the lenticular knots seems to vary with their distance from the contact of the sedimentaries with the later granite intrusives; near the contact garnets are present, farther away biotite crystals take the place of the garnets, and at greater distances impure crystals of siderite form the chief constituent of the lenses. These facts will be considered at greater length in the detailed descriptions of individual occurrences and in the discussion of metamorphism (see p. 107).

The knotted schists always have a fine-grained ground-mass, and in places they closely approach slates, both in fineness of texture and in perfection of cleavage—in fact they have commonly been described as slates; but, since the principal mineral constituents can usually be distinguished with a pocket lens, it has been thought best in this report to classify them all as schists.

The knotted schists constitute one of the most important members of the pre-Cambrian series of sedimentaries, and have a maximum thickness of perhaps 5,000 feet or more. They are interbedded with the other schists and quartzites, and are found in three principal belts. These belts are described below in detail.

DETAILS OF OCCURRENCES.

New Canton.—The best exposures of the knotted schists are furnished by the bluffs along the south side of James River in the vicinity of New

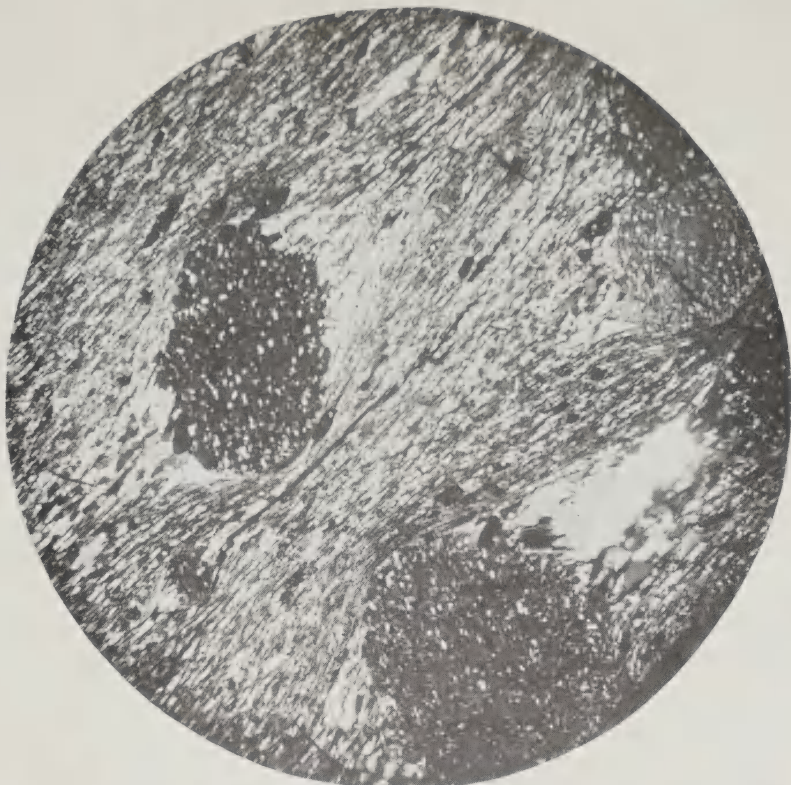


Fig. 1.—Photomicrograph of biotite-bearing knotted schist; thin section cut perpendicular to the schistosity. With analyzer. Magnified 27 diameters. See page 32. Specimen No. 307.



Fig. 2.—Photomicrograph of garnetiferous knotted schist; thin section cut parallel to the schistosity. With analyzer. Magnified 27 diameters. See page 168. Specimen No. 178. Tellurium Mine.

Canton. Here the schists are interbedded with the quartzites described on pages 16-18, and the whole formation is upturned so that the beds are now dipping almost vertical. The average strike is about N. 20° E.

On the east, these schists extend almost to the railroad bridge over Phelps Creek, where they pass into the belt of hornblende schists that occurs along the contact between the granite and the older sedimentaries. This contact and the rocks in its vicinity are described in detail under contact metamorphism on pages 107-112. Near the bridge over James River the schists are interbedded with several beds of quartzite, and west of these the schists continue as far as the belt of Ordovician sedimentaries. The total breadth of the formation is nearly $1\frac{1}{2}$ miles and the whole series is apparently conformable, though it is possible that there has been some close folding resulting in repetition of beds.

The river bluffs and the railroad cuts along the line of the Buckingham Branch of the Chesapeake and Ohio Railway, furnish an almost continuous exposure across the entire formation. The schists on the west side will be described first, as these are farthest from the contact with the granite, and then the variations that are encountered in passing eastward across the formation will be considered in detail.

The rock exposed 1,200 yards west of Bremo bridge and about 2,000 yards west of the contact with the granite, is a fine-grained knotted schist (Spec. 445), dark bluish-gray in color, containing lenticular eyes of impure siderite ranging up to 4 or 5 mm. in diameter. In fineness of texture this rock closely resembles the slates of the Ordovician formation, and but for the fact that it passes by gradation into the true schists, it would probably be preferable to classify it as slate. The rock shows a closely spaced fracture cleavage, which intersects the flow cleavage and bedding at an angle of nearly 90°. Considerable pyrrhotite is present, sometimes forming small lenses, and there are occasional narrow veinlets of calcite. The ground-mass is composed essentially of the micas—chiefly sericite, quartz, and a little carbonate and iron oxide.

A specimen (444) obtained from an outcrop about 1,000 yards west of the bridge is typical of most of the schist found at a distance from the contact. The rock is fine-grained, but is slightly coarser in texture than the specimen last described, and the color is a much lighter shade of gray. It contains numerous small knots due to the presence of lenticular eyes of impure siderite, averaging about 1 mm. in diameter, and a little pyrite and pyrrhotite can be distinguished with the aid of a lens. The rock is cut by occasional veinlets of calcite, usually less than half an inch in thick-

ness, which sometimes show slight symmetrical banding. In thin sections under the microscope the lenses of siderite are seen to be stained with limonite and to contain numerous inclusions of quartz and a few grains of iron oxide and sulphide. The ground-mass is composed essentially of quartz, sericite, and carbonate, with lesser amounts of pyrite, pyrrhotite, iron oxide, chiefly hematite, acid plagioclase feldspar, dark brown prisms of tourmaline, zircon, and a little chlorite.

Schists that are identical in every way with the specimen just described occur within 200 yards of the bridge and are interbedded with the quartzites. Near the bridge, which is about 1,000 yards from the contact, biotite and chlorite begin to take the place of the siderite in the lenticular knots, and it is believed that these changes are chiefly due to the metamorphic action of the granite. From this point eastward the schists show rapidly increasing evidence of contact metamorphism.

A specimen (49)^a from the bluffs about 25 yards west of the bridge is, megascopically, closely similar to the schists already described, but under the microscope it may be seen that many of the knots are composed of biotite, chlorite, and quartz instead of siderite. Lenses of siderite, stained with limonite, are however still present. The ground-mass contains sericite, quartz, chlorite, biotite, pyrite, iron oxide (hematite?), a few small prisms of green and brown tourmaline, zircon, and probably a little feldspar.

A specimen of knotted schist (307) obtained from the bluff 400 yards southeast of Bremono bridge and about 800 yards from the contact, contains numerous rounded crystals of biotite, averaging 1 to 1.5 mm. in diameter, and, rarely, small pink garnets of nearly the same size. The crystals of biotite are dark brown to black in color and the direction of cleavage, which is independent of the schistosity of the rock, shows no regular orientation. They closely resemble the crystals of ottrelite which sometimes occur in similar schists. The ground-mass is slightly coarser in texture than the specimens previously described, and the minerals—quartz, mica, and magnetite—can be distinguished megascopically.

Under the microscope, as shown in Pl. V, fig. 1, the crystals of biotite are seen to have an irregular, ragged outline and a micropoikilitic texture due to the numerous inclusions of quartz. In places these inclusions are so plentiful that they give to the mica an appearance resembling lace-like network. The biotite is dark brown in color and strongly pleochroic. The ground-mass is composed essentially of quartz and sericite with a little

^aSpecimen collected by Dr. T. P. Maynard.

chlorite, biotite, less magnetite, and, rarely, plagioclase feldspar. The quartz occurs in elongated grains, interleaved with fine shreds of sericite, all being perfectly oriented parallel to the schistosity. The small grains of magnetite show a similar elongation parallel to the schistosity, and the slide also contains clouds of uniformly distributed, dust-like inclusions, probably black iron ores, though they are too small to make identification positive. The shreds of sericite, over large areas, extinguish simultaneously except where they curve around the large biotite crystals, and there the change is gradual. This gives the thin section a brilliant appearance between the crossed nicols. Where the flakes of sericite curve around the biotite crystals they are pushed close together, and the interstitial quartz, which has been largely removed from these points, is concentrated immediately in front and behind the biotite, in grains that are somewhat larger than those of the ground-mass.

In passing eastward toward the contact, the crystals of biotite present in the lenticular knots gradually give way to garnets, and the ground-mass becomes a little coarser. At a distance of about 600 yards southeast of the bridge the garnets are numerous and well developed, while the biotite crystals are absent or only sparingly present. Within less than 100 yards from this point the rocks are close-textured, less easily cleavable, and contain much hornblende (see p. 109). A specimen in which the garnets greatly predominate over the biotite crystals (319-A) was obtained from the Johnson mine near New Canton, and is described in detail on pages 254-255.

Rogers described the schists in the vicinity of Bremono under the name of bird's-eye maple slate. His statement is as follows:

"After leaving the gneiss and hornblende slate a little below Bremono, we come upon heavy vertical beds of a *Micaceous slate*, in which are multitudes of half-developed garnets, and sometimes crystals of cubical pyrites—giving to the surface of the rock the appearance of numerous knots, around which the fibres of the stone are beautifully curved, so as closely to resemble the shading of the bird's-eye maple."^a

The belt of knotted schists, that has just been described, extends from the river in a northeasterly direction for a distance of over 6 miles. At the Snead mine, a mile north of Fork Union, a knotted schist is exposed which contains pseudophenocrysts of both garnet and biotite. The belt extends as far south as Willis Mountain and possibly much farther, but good exposures are seldom found after leaving the river. The belt of knotted schists passes just west of Gravel Hill, and crosses the road about

^aRogers, W. B., *Geology of the Virginias*, 1884, p. 78.

1½ miles south of Dillwyn. In this southern portion of the area, the knots in the schist do not seem to be as well developed as farther north, but this may be more apparent than real, for all of the rock examined was partly decomposed.

Strathmore.—On the west side of Brema Creek, about 1,000 yards west of Strathmore, there is an outcrop of knotted schist containing well-developed lenticular eyes of siderite. The rock is more schistose than the similar schists a mile west of Brema bridge, but it is otherwise the same. It outcrops at several points to the northeast and apparently extends for a distance of 5 miles or more in that direction, but on the south side of Slate River it was not found. This belt of knotted schists, while separated from the one that was first described by the intervening Ordovician formation, undoubtedly belongs to the same series and owes its present position to folding and faulting.

The Tellurium schists.—The third belt of knotted schists outcrops in the road at Shannon Hill and may be traced in a southwest direction nearly to Big Byrd Creek. It is best exposed in the underground workings at the Bowles, Tellurium, and Scotia mines. A representative specimen (178) from the Tellurium mine is described on pages 168-169, and a photomicrograph is shown in Pl. V, fig. 2.

Stage Junction.—A bed of micaceous schist, about 300 yards wide, is exposed near Stage Junction. It has a strike of N. 20° E., dipping nearly vertical, and was traced for over 1½ miles. No fresh specimens could be obtained, but the weathered material indicates that the rock is similar to the knotted schists found elsewhere in the area.

Hornblende Schists.

GENERAL CHARACTER AND DISTRIBUTION.

Hornblende schists, that are unquestionably sedimentary in origin, occur at a number of places in the pre-Cambrian area, but the origin of many of the hornblende schists is doubtful, and most of them are probably derived from igneous rocks. Because of the general character and structural relations of these rocks, as well as their distribution relative to the later granites, it is believed that the formation of hornblende schists from sedimentary rocks was due chiefly to contact metamorphism, rather than to regional dynamic metamorphism. Hornblende schists are commonly present along the contact between the igneous and sedimentary rocks; and the few outcrops that were found at a distance from known

occurrences of granite, may be explained by lack of exposures, though in some localities it is possible that erosion has not yet progressed far enough to expose the underlying granite.

As it is seldom possible to distinguish between the hornblende schists that are sedimentary in origin and those that are igneous in origin, and as the majority of these rocks belong to the latter class, most of the occurrences will be described under igneous rocks.

DETAILS OF OCCURRENCES.

New Canton.—One of the best exposures of hornblende schist is furnished by the bluffs along Phelps Creek in the vicinity of New Canton. These schists occur along the contact between the sedimentary schists and quartzites on the west, and the granites and their accompanying differentiates on the east. Since this is the best exposed section crossing the contact, and since the schists that are sedimentary in origin grade, without noticeable change, into the hornblende schists that represent a basic border facies of the granite, a detailed description of all the rocks in the immediate vicinity of the contact will be given under the discussion of contact metamorphism (see pp. 109-112), and nothing further need be said here concerning them. These same hornblende schists are well exposed at the Johnson mine and are described on pages 248-250 and 255-256.

Big Byrd Creek.—At the horseshoe bend in Big Byrd Creek, three-quarters of a mile east of Stage Junction, there is an outcrop of fine-grained hornblende schist, which is believed to be sedimentary in origin. The strike of the formation at this point is N. 35° E. and the dip is 40° S. E. The schist has a well-developed slaty cleavage, which is so marked that it led the owner of the property to prospect the outcrop in the hopes of developing good roofing slate. A garnetiferous quartz-mica schist occurs on the west side of the hornblende schist, and a short distance to the east there are outcrops of quartz-sericite schist. A large dike of diabase cuts the schists about 200 yards from the creek, but has in no way affected the rocks with which it is in contact.

Megascopically the rock is dark gray to green in color, with a fine-grained, even-granular texture, and in places the cleavage planes show lens-shaped spots or blotches, 0.5 cm. in length, which are composed of biotite and chlorite. Small needles of black hornblende and white granular quartz are the principal constituents distinguishable by the naked eye, but some of the rock contains considerable evenly distributed biotite. Occasionally the schist is banded in light- and dark-colored layers parallel to the schistosity; the dark-colored layers being due to the presence of much hornblende and biotite, and the light ones to an excess of quartz. A little pyrite may also be identified in places.

In thin section (Spec. 51) under the microscope the rock is seen to be composed of dark green hornblende, quartz, feldspar, magnetite, biotite, and chlorite. The hornblende occurs in narrow prismatic crystals, ranging up to 2 mm. in length, which show good cleavage and strong absorption, the colors being various shades of brown, blue, and green. The quartz and feldspar are present in small clear grains, filling the interstices between the hornblende, and they occasionally contain small included needles of hornblende. The quartz and feldspar have the same index of refraction and are distinguishable with difficulty, except where the latter mineral shows evidence of cleavage. The magnetite occurs in clusters or aggregates of small irregular grains. The biotite is greenish-brown in color and shows partial alteration to chlorite.

Lantana.—The contact between the igneous and sedimentary rocks crosses the road about half a mile southeast of Lantana, and it is marked by a belt of hornblende schists that are similar to those occurring near New Canton. Exposures of fresh rock are rare in this vicinity, but along the branch, a mile northeast of Lantana, there are several outcrops of hornblende schist.

A partly decomposed rock, outcropping on the left bank, is medium coarse-grained and dark green in color. The mineral constituents recognizable megascopically are dark green hornblende, quartz, probably feldspar, and a little garnet, and chlorite. A prismatic mineral (probably tremolite), which is light green to brown in color, is also present.

A specimen (90) obtained from the opposite side of the branch is finer grained and much fresher. It is an even-granular, dark greenish-gray schist, in which amphibole, quartz, pyrite, and magnetite are the principal constituents. Part of the amphibole is green in color, but much of it is light gray to nearly colorless, and is doubtless tremolite. In thin sections under the microscope, the amphiboles are all colorless in natural light, and between the crossed nicols most of them show rather high interference colors. Twinning is sometimes shown. There is also a little acid plagioclase present, which is usually unstriated and therefore difficult to distinguish from the quartz.

Gneisses.

GENERAL CHARACTER AND DISTRIBUTION.

Gneisses, believed to be sedimentary in origin, are found only in one portion of the area of pre-Cambrian rocks, namely, along the eastern border, north of James River, in the vicinity of Lantana. These gneisses are best exposed along Big Byrd Creek, between Bowles' bridge, 1½ miles

northeast of Stage Junction, and the contact of the sedimentaries with the granites, nearly two miles below. Away from the creek there are few outcrops; but float is present in many places, being especially abundant near the branch $1\frac{1}{4}$ miles northeast of Lantana, and the underground workings of the Young American mine furnish excellent exposures of fresh material. All of these gneisses are confined to the area of metamorphosed sedimentaries lying on the southeast side of an imaginary line, which extends from a point on Big Byrd Creek, a few yards above Bowles' bridge, in a northeast direction through Pryors Crossroads. No knotted schists are found on the southeast side of this line. It appears certain that the areal distribution of the sedimentary gneisses was once much greater than at present, and they probably extended for a considerable distance toward the northeast and the southeast; but the greater part of these beds has long since been removed by erosion.

Two principal varieties of gneiss were recognized—one light in color and composed for the most part of quartz, feldspar, and sericite; the other dark-colored because of the presence of more or less biotite and dark green hornblende. Both usually show well-developed banding. These two varieties occur interbedded with one another, and with beds of sericite quartzite, ferruginous quartzite, and quartz-sericite schists. The dark-colored gneiss is confined to the northwestern side of the belt and is the dominant rock exposed in the openings at the Young American mine, but its areal distribution is not so extensive as that of the lighter variety.

GENESIS.

The manner in which these gneisses are interbedded with one another and with the quartzites, leaves no doubt as to their sedimentary origin. Analyses of both the dark- and light-colored gneisses, made from samples taken 100 feet below the surface at the Young American mine, are given on page 124. The analyses show a striking resemblance in chemical composition between these metamorphosed sedimentaries and igneous rocks of the quartz-diorite family. It is therefore probable that the sediments were derived from a land area composed chiefly of such rocks, and that they were laid down in comparatively shallow waters close to the shore. The conditions under which such material was derived did not permit mature decomposition; the land area was probably poorly covered by vegetation, rock disintegration was rapid, and the material formed was quickly removed and redeposited without appreciable sorting. The sediments laid down in this manner formed beds of arkosic sandstones and grits; and the present character of the rocks is due to dynamic regional metamorphism, aided by the intrusion of the granitic rocks that partly surround and probably underlie these altered sediments at no great depth.

DETAILS OF OCCURRENCES.

Young American mine.—The freshest exposures of both the light and the dark varieties of gneiss were found in the lower workings of the Young American mine; and detailed megascopic and microscopic descriptions of these rocks, together with chemical analyses, are given under the description of this property (see pages 122-139). The difficulty of obtaining fresh material—for microscopic study and chemical analysis—may be appreciated when it is stated that, in the Young American mine, some of the rock is badly decomposed to a depth of nearly 100 feet below the surface.

Bowles' bridge.—On the road between Stage Junction and Pryors Crossroads, near the bridge over Big Byrd Creek, there are well-exposed outcrops of light gray gneiss. The rock (Specs. 39 and 40) is fine-grained, even-textured, and slightly banded; both in the hand specimen, and in thin section under the microscope, it closely resembles a fine-grained granite-gneiss. It is composed essentially of quartz, orthoclase and acid plagioclase feldspars, and sericite. Much calcite, probably secondary in origin, can be distinguished under the microscope; biotite is present in small dark green flakes, partly altered to chlorite; and small amounts of pyrite, magnetite, and zircon constitute the minor accessories. Some of the quartz grains show undulatory extinction, but for the most part there is little evidence of optical distortion or granulation. The sericite occurs in fairly large flakes, containing numerous inclusions of quartz, and it is partly of later origin than the schistosity.

About 400 yards below the bridge there is an outcrop of dark gray gneiss (Spec. 35), which is apparently identical in mineral composition as well as in texture with much of the rock exposed in the Young American mine. It is fine-grained, closely banded in layers of light and dark minerals, and composed for the most part of quartz, feldspar, biotite, chlorite, sericite, and occasional garnets. Elsewhere in the same vicinity the rock contains much dark green hornblende.

Bertha and Edith mine.—On Big Byrd Creek, about 1,000 yards south of Bowles' bridge, there is an exposure of light gray gneiss (Spec. 32) similar in appearance to that at the bridge, except that it is slightly coarser grained. Much of the sericite occurs in large flakes in which the cleavage is not parallel to the schistosity, showing that it is of later formation than the movements which metamorphosed the sediments. The minerals present, in the order of their relative abundance, are quartz, feldspar, chiefly acid plagioclase, sericite, biotite, chlorite, magnetite, pyrite partly altered to limonite, zircon, and titanite. Calcite was not identified.

On Big Byrd Creek, a mile south of Bowles' bridge, the gneiss (Spec. 30) is a light gray, fine-grained rock, differing but little from the specimens previously described. It contains less sericite, and under the microscope considerable epidote or zoisite can be detected.

Where the road entering the property crosses Great Camp Branch, there is an outcrop of the light gray gneiss, which is within about 300 yards of the contact of the sedimentaries with the granite. The rock (Spec. 48) is composed of quartz, feldspar, and sericite, with lesser amounts of biotite, partly altered to chlorite, garnet, zircon, and magnetite.

Belzoro mine.—Near the branch half a mile north of Lantana, there are numerous pieces of the light gray gneiss lying loose on the surface, but there are no outcrops of rock in place. The same material is plentiful in the vicinity of the other branch, nearly a mile to the northeast. This gneiss (Spec. 85) is slightly banded, and, except for the sericite, is fine-grained. Some of the areas of sericite are a centimeter in diameter, and as the orientation of the cleavage is independent of the schistosity of the rock they must be of later formation. Even in the hand specimen the flakes of sericite are seen to be full of included quartz grains. Under the microscope the rock is seen to be composed chiefly of quartz, sericite, feldspar, with lesser amounts of biotite, partly altered to chlorite, epidote, garnet, magnetite, zircon, and rutile needles. Some of the feldspars show partial alteration to sericite, and this is probably the chief source of the mica. In places the sericite shows intergrowths with biotite. Zircon and rutile needles are very plentiful as inclusions in some of the quartz.

ORDOVICIAN.

General Statement.

The Ordovician rocks are for the most part confined to a long narrow belt, which extends in a northeasterly direction from a point near Alpha, a station on the Buckingham Branch of the Chesapeake and Ohio Railway, to Carysbrook, a station on the Virginia Air Line Railway. A small elongated area of the same formation, located along the upper portion of Long Island Creek, between Palmyra and Wilmington, is in approximate alignment with the larger belt; and it seems most likely that the two areas were formerly continuous, and that they have been separated by the erosion of Rivanna River, which has removed the overlying sedimentary rocks, exposing the granite beneath.

Another small area, which parallels the main belt for a short distance, has been prospected for slate at a point about 2 miles north of Fork

Union Station. It was undoubtedly connected at one time with the main area, and has become separated through folding and erosion.

The principal belt has a maximum width near James River of over a mile, but it probably averages less than half a mile; the total length, including the detached area on the northeast side of Rivanna River, is about 22 miles.

The Ordovician series, where complete, consists of a thin bed of conglomerate, overlain by a few feet of impure quartzite, and then followed by several hundred feet of slate. In places the conglomerate is composed of mashed pebbles of pre-Cambrian schist, and when these are small, the fragmental character of the rock is distinguishable with difficulty. At one point a layer of tuffaceous material, a few feet thick, occurs interbedded with the slates.

The discovery of crinoids in slate from the Arvonias quarries was announced in 1892, and from a study of these fossils Dr. Walcott reached the conclusion that they belonged to the Trenton-Lorraine or upper portion of the Ordovician fauna.^a Later brachiopods and trilobites were found, and, according to Dr. R. S. Bassler, the twelve species which have been identified "make up an assemblage of forms which seems to be of middle Cincinnati age."^b

Conglomerate.

GENERAL CHARACTER AND DISTRIBUTION.

The conglomerate occurs only at the base of the Ordovician rocks, where it rests upon the eroded surface of the metamorphosed, pre-Cambrian sediments and in places upon the granite. On the south side of James River the conglomerate is found along the southeastern boundary of the slate area, but has not been observed on the northwest boundary. It is not exposed in the section furnished by the bluffs along the river, probably because of minor faulting, which is very marked in the vicinity of the place where the conglomerate would be expected to appear. It outcrops, however, within about half a mile of the bluffs and can be traced southward for a distance of several miles. On the north side of the river the conglomerate was observed only on the west side of the slate, occurring on the road between Palmyra and Wilmington, about a quarter of a mile west of Long Island Creek, and in the railroad cut half a mile south of Carysbrook.

^aDarton, N. H., Fossils in the "Archæan" Rocks of Central Piedmont, Virginia, *Amer. Jour. Sci.*, 1892, vol. xlv, pp. 50-52.

^bWatson, Thomas L., and Powell, S. L., Fossil Evidence of the Age of the Virginia Piedmont Slates, *Amer. Jour. Sci.*, 1911, vol. xxi, pp. 33-44.

The lack of suitable exposures makes it impossible in most places to determine the thickness of the conglomerate. Outcrops in the vicinity of Penlan indicate a possible thickness of perhaps 100 feet, but as the dip of the strata could not be determined at this point, the measurement means little. In the railroad cut south of Carysbrook the conglomerate is only a few inches thick and in places entirely disappears.

The composition of the conglomerate varies greatly in different portions of the area; in places it consists almost entirely of flattened pebbles of schist, but pebbles of vein quartz and of quartzite are usually present, and sometimes there is much magnetite, graphite, and other material. No granite or feldspar pebbles were found. The rock is usually schistose and, where the quartz pebbles are scarce, is easily mistaken for a pre-Cambrian schist. The pebbles of vein quartz show no pressure effects, those of quartzite are usually more or less distorted, and all the softer material is pressed out flat.

DETAILS OF OCCURRENCES.

Penlan.—There are prominent outcrops of conglomerate along the county road about three-quarters of a mile southeast of Penlan. The rock contains well-rounded pebbles of quartz and also of quartzite, ranging up to 2 or 3 inches in diameter; but for the most part it consists of a fine-grained schistose ground-mass, which has been derived from pebbles of the neighboring pre-Cambrian schist. In places it is possible to distinguish flattened and almost obliterated fragments of quartz-sericite schist and of the slate-colored, knotted schist.

When the schistose ground-mass is examined under the microscope (Spec. 462), clear rounded grains of quartz, ranging up to 1.5 mm. in diameter, can be distinguished in a ground-mass consisting chiefly of sericite, chlorite, quartz, and black oxide of iron. The larger quartz grains seem to have grown slightly at the expense of the surrounding material, for they have irregular outlines, with little spurs running out into the ground-mass, and frequently contain numerous inclusions along their border portions. Gas and fluid inclusions are plentiful in some of the quartz. Glistening plates of hematite, and a few grains of magnetite make up the remaining accessories.

Outcrops of conglomerate similar to that just described are exposed along the road running northeast and southwest, about half a mile southeast of Arvonja, and at numerous other points along the same line of strike.

Carysbrook.—In the railroad cut half a mile south of Carysbrook, the Ordovician sediments can be seen resting directly on the eroded surface of the granite (see Pl. VI, fig. 1). There is in most places a thin line of pebbles in contact with the granite, but sometimes even this is absent.

A bed of impure quartzite, about 10 feet thick, rests on top of the conglomerate, or where this is absent on the granite, and above the quartzite occurs the slate. The pebbles are chiefly of quartz, but fragments of slaty rock are present, and also much graphitic material. The latter is soft, disintegrating rapidly, and leaving cavities in the weathered surface. The pebbles are cemented together by fine-grained, impure quartzite.

Long Island Creek.—There is an outcrop of highly ferruginous conglomerate on the road between Palmyra and Wilmington, about a quarter of a mile west of Long Island Creek. The rock is dark gray, very schistose, and consists of flat, lens-shaped pebbles of quartzite, in a chloritic ground-mass, containing a large amount of fine-grained magnetite. Under the microscope (Spec. 486) the magnetite apparently constitutes 40 or 50 per cent. of the mass, the remainder being made up of quartz, chlorite, and sericite, in the order named. The smaller grains of magnetite are commonly idiomorphic, but the larger grains, ranging up to 1 or 2 mm. in diameter, are irregular in shape.

Quartzite.

The best exposure of Ordovician quartzite is the one which may be seen in the railroad cut, half a mile south of Carysbrook. The rock is only about 10 feet thick and varies somewhat in texture. It is nearly even-granular, slightly schistose, and of a light bluish-gray color. In thin sections (Specs. 509 and 510) under the microscope, the quartz grains show optical distortion and some granulation, and they have partly recrystallized so as to fill the interstitial spaces. They contain liquid- and gas-filled cavities, and small black inclusions (iron oxide?) arranged in lines which pass across the quartz grains. In places these lines are very numerous, suggesting fractures that have been recemented. Sericite is the principal impurity, and there are occasional short prisms of brown tourmaline. Zircon and small rutile needles occur as inclusions in some of the quartz.

A bed of quartzite also outcrops in the road about half a mile southeast of Penlan, but its thickness could not be determined. It is separated from the conglomerate described on page 41 by a bed of schist which is probably formed chiefly from fragments of the pre-Cambrian schist.

Schist.

A light gray schist, closely resembling some of the pre-Cambrian schists, outcrops in the road about half a mile south of Arvon, and not



Fig. 1.—Ordovician sediments resting on eroded surface of massive granite near Carysbrook. A thin line of conglomerate runs between the hat and hammer.



Fig. 2.—Looking north along summit of Willis Mountain. Piedmont peneplain in background.

ORDOVICIAN SEDIMENTS ON GRANITE, AND WILLIS MOUNTAIN.



Fig. 1.—Bed of tuff in Ordovician slates. Bluffs on the south side of James River.



Fig. 2.—Fault in Ordovician slates. Bluffs on south side of James River.

BED OF TUFF AND FAULT IN ORDOVICIAN SLATES.

far from the conglomerate. The rock is clearly fragmental in origin and exhibits two directions of cleavage—one due to bedding, and the other to pressure—which intersect at an angle of about 40° . It is composed essentially of quartz, sericite, and chlorite, and contains occasional lenticular eyes of quartz 1 to 2 mm. in diameter. Under the microscope (Spec. No. 1)^a the lenticular eyes are seen to be partly quartzite, and partly clear grains of quartz, some of which show evidence of enlarged borders. Liquid and gas inclusions, and a little zircon and titanite may also be identified. This rock is similar to the schist which occurs between the conglomerate and the quartzite about half a mile southeast of Penlan.

Tuff.

A bed of tuffaceous material is exposed in the bluff near the eastern border of the slate area and a mile west of Brema bridge. It is interbedded with black graphitic slates, which in places contain much pyrite. A photograph of the bed is shown in Pl. VII, fig. 1. Close to the hammer a nearly vertical fault can be seen, on the left of which the beds stand almost vertical, while on the right they are much contorted but nearly horizontal. The tuff is the light-colored material near the hammer. No other beds of tuff were identified in the area.

The tuff (Spec. 494) is a fine-grained, gray, slate-colored rock, distinctly fragmental to the naked eye, and very schistose, so that the fragments are drawn out in long streaks. Fine flakes of sericite, small grains of quartz, and a little pyrite are the only minerals distinguishable megascopically. Under the microscope it is seen to consist chiefly of fine-grained quartz, sericite, with numerous larger grains of quartz, averaging less than 0.5 mm. in diameter, and occasional small phenocrysts of feldspar (orthoclase and acid plagioclase). Calcite is plentifully distributed through the section, and pyrite partly altered to limonite, occurs in small grains. Very fine, dust-like inclusions (graphite or iron oxide) are abundant throughout the slide.

Slate.

GENERAL CHARACTER AND DISTRIBUTION.

Slate is the dominant rock of the Ordovician series of sedimentaries, and the beds probably have a thickness of more than 1,000 feet, but because of the complicated folding and faulting only a rough estimate can be made. The areal distribution of the slate is coincident with that of the formation as a whole, for the thickness of the other members is insignificant in comparison with that of the slate.

^aMicroscopic thin section made from specimen collected by Dr. T. P. Maynard.

The slate has a finely granular, crystalline texture, it is dark gray to black in color, and usually has a rather rough though very lustrous cleavage surface. It is graphitic and usually slightly magnetitic, contains a little pyrite, does not effervesce in cold dilute hydrochloric acid, and is very sonorous. The degree of cleavability varies greatly in different parts of the area, but is usually high, so that the slate can be split readily into slabs of any desired thickness.

In the vicinity of Arvonía the slate has been extensively quarried for roofing and other purposes, and at a number of places along the strike of the formation prospecting has been carried on with very encouraging results. Because of its highly crystalline character, the slate has great strength and durability, and some of it, used in roofing buildings over a century ago, shows no discoloration from its long exposure. All of the slate in this area is not, however, available for commercial purposes, as the value of some of it is destroyed by close folding and faulting, and in a few localities the cleavage is not sufficiently developed.

DETAILS OF OCCURRENCES.

A detailed report on the slate deposits of Virginia is now in preparation, and will be published shortly as Bulletin No. X of the State Geological Survey; therefore the following descriptions will be brief, and for the most part limited to facts bearing on the structural relations of the slate formation.

Arvonía.—At Arvonía there are extensive quarries, all of which are located on the east side of the slate belt. In these openings the bedding and cleavage of the slate are identical, striking N. 33° to 37° E. and dipping 70° to 90° southeast. There are three sets of joints, namely, vertical dip joints striking northwest; strike joints, running northeast and southwest and dipping 70° to 80° southeast; and diagonal joints some of which dip 30° east while others dip 55° west. Quartz veins are occasionally present, some of which contain calcite, and a little chlorite and biotite. In one of the quarries a dike of olivine diabase is exposed, which is 12 feet thick and traverses the slate diagonally.

The slate is very dark gray, with a faint greenish hue; it shows a distinctly granular crystalline texture to the naked eye; and has a highly lustrous cleavage surface, which is commonly rough or slightly wrinkled because of the presence of small flakes of biotite and of minute grains of the iron ores. According to Dale^a the mineral constituents, in the order

^aDale, T. N., *Slate Deposits and Slate Industry of the United States*, Bull. U. S. Geol. Survey, No. 275, 1906, p. 114.

of their relative abundance, are muscovite and sericite, quartz, biotite, carbonate, graphite (or carbonaceous matter), pyrite, chlorite, magnetite, with accessory plagioclase, zircon, hematite, tourmaline, and rutile.

The following microscopic description of the slate from the Williams quarries is given by Dale, and may be taken as representative of the other quarries in this vicinity:

"Under the microscope it shows a matrix of minute alternating beds, chiefly of fine muscovite, with coarser ones, chiefly of quartz, the former with a brilliant aggregate polarization, the latter with a faint one. These beds are parallel to the cleavage. The quartz fragments measure up to 0.085 mm. Scattered throughout both the more micaceous and the more quartzose beds are crystals, lenses, and particles of pyrite, numbering about 25 to each square millimeter and measuring up to 0.09 mm., rarely 0.15 and 0.42, with their longer axes parallel to the cleavage. These probably include a little magnetite. There are also biotite scales transverse to the cleavage, about 22 per square millimeter, and measuring up to 0.12, rarely 0.2 mm. Almost, if not quite, as abundant are plates and rhombs of carbonate. There are occasional scales of chlorite interleaved with muscovite, a few grains of plagioclase feldspar 0.047 mm., rarely one of zircon, some tourmaline prisms 0.014 mm. long, much extremely fine graphitic (or carbonaceous?) material, a few particles of hematite, and some rutile needles. Sections parallel to the cleavage are unusually brilliant in polarized light, owing to the abundance of quartz, biotite, and carbonate."^a

Bluffs along James River.—The slates exposed in the bluffs along the south side of James River show evidence of much close folding and faulting (see Pl. VII). Near the fault shown in Fig. 2, which is located close to the railroad, 500 yards south of the mouth of Slate River, the slate has two equally developed cleavages intersecting at an angle of about 5°. One of these is the ordinary slaty cleavage due to pressure, and the other is probably slip cleavage due to minute faulting. As the two cleavage surfaces reflect light at slightly different angles, the slate has a very striking appearance. About a quarter of a mile farther east a similar slate is exposed, in which the angle between the two cleavages is 25°, but one is much better developed than the other. It is possible that one cleavage is due to bedding.

Some of the slates are highly graphitic, and in others pyrite is very plentiful, occurring in thin layers parallel to the bedding. Hematite is occasionally present in the form of thin plates, a fraction of a millimeter in diameter.

Carysbrook.—The slate exposed in the railroad cut half a mile south of Carysbrook is wholly lacking in slaty cleavage, but has a distinctly

^aDale, T. N., *Ibid.*, pp. 113-114.

schistose structure parallel to the strike of the formation, which causes the rock to break in roughly prismatic shapes. This peculiarity is probably due to the location of the material at the bottom of a synclinal fold, where the pressure was approximately equal in all directions except along the axis of folding.

The strike of the formation is about N. 25° E. and there are three principal sets of jointing, namely, nearly vertical strike joints running northeast and southwest; joints which dip about 30° southeast and are approximately parallel to the contact with the underlying granite; and transverse joints having a strike of N. 60° W. and dip of 75° northeast. The latter are spaced 2 to 8 inches apart.

The slate (Spec. 505) is dark gray, with little luster, and contains numerous flat discs of specular hematite, which are oriented in all directions parallel to the axis of folding. These plates vary in diameter up to 1 mm. and in thickness up to 0.1 mm.

Examined microscopically the chief constituents of the ground-mass are, in the order of their relative abundance, sericite, quartz, chlorite, with accessory tourmaline, and zircon. Some of the quartz occurs in lenticular eyes less than 0.5 millimeter in length, which occasionally contain small fragments of zircon. Prisms of greenish-brown tourmaline, ranging up to 0.2 millimeter in length, are fairly plentiful, and are usually oriented parallel to the schistosity. Some of the thin discs of hematite contain numerous small inclusions of quartz.

TRIASSIC.

The small area of sedimentary rocks shown on the map (Pl. I), between Ca Ira and Willis Mountain, belongs to the Triassic (Newark) system, and is the northern end of the Farmville area, which extends in a southwesterly direction for a distance of over 20 miles. In this northern portion the rocks consist of gently dipping beds of conglomerate, sandstone, and shale. They are deep red in color, and are in marked contrast to the surrounding crystalline rocks, chiefly granite and pegmatite, which weather to a light gray soil. Near Farmville fine, light-colored sandstones and shales occur interbedded with several small coal seams, the lighter color being undoubtedly due to the reducing action of the carbonaceous matter.

The area as a whole is, topographically, a basin surrounded by hills of crystalline rocks, but lack of exposures make it difficult to work out the detailed geologic structure. The stratified rocks of the Triassic rest un-

conformably on the metamorphosed pre-Cambrian sediments and the granites; and these underlying formations dip steeply toward the south-east. The Triassic beds are much disturbed, changing abruptly from northeast to southwest dips, and Russell determined the presence of at least four north and south faults.^a One of these faults forms the eastern border of the area about 2 miles north of Farmville, and there the stratified rocks are much broken and slickensided. In the absence of better exposures, it is impossible to measure the thickness of the beds, but everything indicates that they are of no great depth.

The rocks of the Triassic system have not undergone the great crustal movements which have so intensely metamorphosed the older rocks of the area; indeed, for the most part, they have not been thoroughly consolidated. Since these rocks have not extensive areal distribution in the region mapped, and since they are of no economic importance, they will not be discussed in this report.

ROCKS IGNEOUS IN ORIGIN.

GENERAL CLASSIFICATION.

The rocks of igneous origin described in this report are classified, in so far as possible, according to their relative age. The position of some of these rocks in the geological column is accurately known, that of others can be determined within comparatively narrow limits, and in a few instances there is considerable uncertainty. As in the case of the sedimentary rocks, the chief criterion used in distinguishing between the pre-Cambrian and the later rocks is that of relative schistosity, while the position of others is determined by their relation to sedimentaries of known age. Under the description of each rock type, the evidence upon which its age classification is based is given in detail. The principal groups into which the igneous rocks have been divided are: (1) Pre-Cambrian, (2) pre-Cambrian and Cambrian, (3) Cambrian or post-Cambrian, and (4) Triassic.

PRE-CAMBRIAN.

Greenstone Schists.

GENERAL CHARACTER AND DISTRIBUTION.

A large area of greenstone schists is present along the northwestern border of the map, given on Pl. I, and extends for several miles to the westward. The southeast contact between these schists and the other pre-Cambrian rocks crosses James River about 1,000 yards west of Strath-

^aRussell, I. C., Correlation Papers. The Newark System. Bull. No. 85, U. S. Geol. Survey, 1892, pp. 88-89.

more, and continues in a general southwesterly direction for an unknown distance; passing northeast the greenstone schists apparently pinch out in the vicinity of Palmyra. On Slate River, 500 yards west of Hunts Creek, Ordovician slates are apparently in contact with the greenstone schists for a short distance.

Chloritic schists are common in the region between Wilmington and Kent's Store, and occur at several other localities in the area mapped, but as these rocks are derived chiefly from the hornblende schists that are found associated with the granites, they will be described under that heading.

The rocks in the large area of greenstone schists vary in texture from dense aphanitic varieties to those that are medium fine-grained, and in places porphyritic. They usually show a pronounced schistose structure but some of the coarser grained rocks, which have undergone less alteration, are more nearly massive. The color is always green, and varies in shade according to the relative amounts of chlorite and epidote present in the rock.

The mineral constituents present in these rocks are quartz, chlorite, epidote, amphibole, calcite, plagioclase, magnetite, pyrite, and in some instances small amounts of rutile, ilmenite, and titanite. Very rarely a little chalcopyrite or malachite can be identified.

Quartz and usually calcite are present in the ground-mass of the rock and these minerals also frequently occur as eyes and veinlets. The feldspars, and part of the quartz and magnetite, are the chief primary minerals that remain unaltered. The feldspars are basic plagioclase, and frequently show Carlsbad as well as albite twinning. Chlorite is abundant in all of the rocks, occurring in fine-grained dark green scales. Epidote is most plentiful along fracture lines, and it also occurs in some of the veinlets.

Small slickensided surfaces are common throughout the rock; they run in various directions but are usually approximately parallel to the schistosity. They are probably to be explained by the volumetric expansion which has resulted from the alteration of the rock, with the formation of hydrous from anhydrous silicates.

Microscopic examination of a large number of thin sections of the greenstone schists, shows that they are derived from basic igneous rocks, but the alteration has been so extensive that in most cases it is impossible to determine their original character. The texture in a few localities suggests that part of the schists were formed from massive rocks of deep-seated origin, but it is not improbable that they are largely derived from basic lava flows.

AGE.

The intense regional metamorphism which has affected all of the older rocks, and the lack of suitable exposures along the contact, make it impossible to determine the relation of the greenstones to the other pre-Cambrian schists. When the surrounding portions of the Piedmont province have been mapped in detail some light will probably be shed on this question, but at present it is not even possible to make a statement concerning the relative age of the two formations. At the London and Virginia mine (see pp. 185-186) a chloritic schist is interbedded with the quartz-sericite schists but it is different in appearance and has probably had a different origin. The greenstone schists are classified as pre-Cambrian in age because of their extensive metamorphism under dynamic conditions, and because of the presence of gold-bearing quartz veins believed to be Cambrian in age. They resemble the Catoclin schist of the Blue Ridge and may be contemporaneous in age.

DETAILS OF OCCURRENCES.

Slate River.—The bluffs along Slate River, west of the mouth of Hunts Creek, furnish some of the best exposures of greenstone schist that are to be found in the district, and this section will be described in detail. The contact between the Ordovician slates and the greenstone schists crosses Slate River about 500 yards west of Hunts Creek, but is not exposed. On the south bank of the river just west of the contact there is a bold, cliff-like outcrop of the schist.

The rock (Spec. 495) is dark green, fine-grained, even-granular, and not quite as schistose as in most localities. Quartz, chlorite, and a few small cubes of pyrite are the only minerals recognizable megascopically. Under the microscope the rock is seen to be composed of quartz, chlorite, plagioclase feldspar, calcite, talc, epidote, and a little fine-grained magnetite. The quartz grains are slightly larger than the other minerals, and are frequently arranged in irregular lines and flat lenses parallel to the schistosity. The feldspars are ragged in outline and show extensive alteration to the secondary minerals of which the rock is chiefly composed. The chlorite and other minerals are very fine-grained.

A few yards farther west the rock (Spec. 448) is slightly finer grained, more schistose, and contains occasional lenticular eyes of fine-grained white quartz 3 or 4 mm. in diameter. Examined under the microscope the lenticular eyes are seen to consist of clear rounded, interlocking grains of quartz, which contain small gas- and liquid-filled cavities and numerous

rutile needles. Basic plagioclase feldspars are present, some of which show fractures filled with a fine-grained ground-mass, consisting chiefly of chlorite. Calcite, epidote, and zoisite make up the remaining mineral constituents.

Greenstone schists, essentially similar to those just described, continue for several miles up the river with only a little variation here and there. In one place a peculiar veinlet (Spec. 449) about a quarter of an inch wide, was seen cutting the schist. It consists of dark green micaceous chlorite, with cleavage parallel to the walls, and phenocrysts of white feldspar, 3 to 4 mm. long, which project out from the walls of the veinlet. The feldspars show twinning after both the Carlsbad and the albite laws. Nearly a mile west of the creek, a light green rock outcrops which is nearly massive in texture. It is medium coarse-grained, and is composed for the most part of light green hornblende and feldspar. The hornblende is partly altered to chlorite. It is evidently an igneous rock (probably diorite), which has been only slightly altered.

At the Lightfoot mine, on the southeast side of Slate River, 2 miles northwest of Arvon, the country rock is the typical greenstone schist found everywhere in this section. It is described in detail on pages 241-242.

Lightfoot farm.—On the farm of P. W. Lightfoot, $1\frac{3}{4}$ miles N. 15° E. of Arvon, an 18-foot shaft has been sunk in prospecting for copper. Most of the rock exposed on the dump is a fine-grained greenstone schist containing scattered crystals of pyrite, less than 0.5 mm. in diameter, and much fine-grained magnetite. In places there are small segregated areas containing pyrite in coarse, irregular crystals associated with white quartz. A few pieces of rock were seen which contained partly altered phenocrysts of feldspar, 2 cm. in length.

At several points in this vicinity a few small specks of malachite can be seen in the country rock. Pebbles of magnetite are found on the surface in places where they have weathered out from the greenstone.

Anaconda mine.—The greenstone schist at the Anaconda mine, near Eldridge Mill, is described on page 244. About 400 yards northeast of the mine several small surface openings have been made in prospecting for asbestos. Some chlorite schist is exposed in these pits, but most of the rock is a light green talc which usually contains a few scattered needles of amphibole, probably actinolite. In places there are large masses of amphibole asbestos, part of the fiber being 7 to 8 inches in length, but much of it is cut by joint planes spaced about 2 inches apart. Masses, composed chiefly of actinolite in more or less radiating crystals, are present

on the dump. Magnetite in small grains is scattered through both the chloritic and talcose schists.

Shores.—A quarry for railroad ballast is located on the Chesapeake and Ohio Railway about three-quarters of a mile southeast of Shores. The rock exposed is dark green in color, fine-grained, and is cut by numerous small segregation veinlets consisting of white, fine-grained quartz, and a little calcite and dolomite. These veinlets do not have sharp, well-defined walls but pass by gradation into the schist. The minerals present in the rock, which can be identified megascopically, are quartz, chlorite, calcite, magnetite, and epidote. The greenstone schist extends westward beyond Shores.

Hughes mine.—The gold veins at the Hughes mine, which is located on the Virginia Air Line Railway, 2 miles northeast of Fork Union station, occur in an area of greenstone schist. Specimens of the wall rock from this mine are described in detail on pages 182-183.

Palmyra.—In the vicinity of Palmyra and northwest from the town a greenstone schist is exposed, and in places the chloritic schists enclose masses of talc and steatite which have been worked to a limited extent. It is reported that a little copper ore was found on the west side of Rivanna River opposite Palmyra, occurring in greenstone schist similar to that near the Lightfoot mine.

Quartz-Feldspar Porphyries.

A series of quartz-feldspar porphyries are exposed along Rivanna River about a mile south of Palmyra. These rocks vary from light to dark gray in color and from fine- to medium-grained; they are usually porphyritic to the naked eye, containing feldspar phenocrysts and eyes of blue opalescent quartz; and they all exhibit varying degrees of schistosity. In thin section under the microscope they are seen to consist essentially of quartz, potash and soda-lime feldspars, and certain secondary minerals such as sericite, calcite, chlorite, and epidote. The eyes of quartz usually show strain shadows, more or less fracturing, and granulation; and they frequently contain rutile needles and gas- and liquid-filled cavities. The potash feldspars include both orthoclase and microcline, and these as well as the acid plagioclase are extensively altered with the production of the secondary minerals mentioned above. There is also a little micropertthite in some of the rock. The minor accessories comprise magnetite, ilmenite partly altered to leucoxene, titanite, and pyrite.

Rocks similar to these porphyries were not found elsewhere in the area mapped. It is possible that they are genetically connected with the in-

trusive granites, but no evidence in support of this supposition could be discovered. For the most part these porphyries are more schistose than the granites and therefore they are probably older.

Rhyolites.

GENERAL DESCRIPTION AND AGE RELATIONS.

Rhyolites occur interbedded with schists and other rocks at several points near the western border of the area mapped, but they are of no importance as geologic formations. They are light gray, hard, dense-textured rocks, and all show a schistose or slaty cleavage, which becomes more marked in the weathered specimens. Watson and Powell noted the occurrence of these rocks south of James River in the Arvonian slate belt and described similar ones in the Quantico slate belt, where they occur interbedded with the slates which are Ordovician in age.^a The rhyolites in the James River section may be contemporaneous with those in the Quantico belt, but the writer found no evidence to indicate that this is true. Because of their marked schistosity they are here described with the pre-Cambrian rocks, although it is possible that they are younger.

DETAILS OF OCCURRENCES.

Bremo Bluff.—On the south side of James River, about three-quarters of a mile west of Bremo bridge, there is an exposure of rhyolite, about 20 feet thick, which is interbedded with knotted schists. The rock is light gray, dense-textured, and in places contains elongated spots due to gas cavities or to some mineral which has undergone decomposition. It has a slaty cleavage, which, while scarcely noticeable in the fresher specimens, becomes very prominent in the weathered rock. Under the microscope (Spec. 493) the rock is distinctly schistose and is seen to be composed of quartz, feldspar, biotite, chlorite, black iron oxide, partly magnetite, sericite, zircon, tourmaline, titanite, and small areas of glass.

Slate River.—On the south side of Slate River about half a mile west of Hunts Creek there is a small outcrop of siliceous rock (Spec. 450), which is hard, close-textured, white in color, and very schistose. It is probably a metamorphosed rhyolite. This rock occurs in the area of greenstone schists derived from basic igneous rocks.

Ballinger Creek.—About $1\frac{3}{4}$ miles east of Palmyra on the road to Wilmington, and 200 yards east of Ballinger Creek, there is an outcrop

^aWatson, Thomas L., and Powell, S. L., Fossil Evidence of the Age of the Virginia Piedmont Slates, Amer. Jour. Sci., 1911, vol. xxxi, pp. 33-44.

of rhyolite which is closely similar to the rock found west of Bremono bridge. It is slightly more schistose in the hand specimen (485) and in thin section under the microscope it is seen to be porphyritic, containing phenocrysts of quartz and acid plagioclase feldspar about 0.25 mm. in diameter. The quartz eyes contain gas- and liquid-filled cavities. The ground-mass is composed of quartz, feldspar, biotite, chlorite, and sericite.

Palmyra.—A short distance south of the railway station at Palmyra there is an outcrop of schistose rhyolite, in which small eyes of quartz can be distinguished by the naked eye. Examined in thin section (Spec. 14)^a under the microscope, small eyes of quartz and phenocrysts of orthoclase, 1 mm. in length, which usually show Carlsbad twinning, can be seen in a fine-grained ground-mass, consisting of quartz, feldspar, magnetite, ilmenite partly altered to leucoxene, and a little chlorite and epidote.

PRE-CAMBRIAN AND CAMBRIAN.

Granites, Their Associated Pegmatites and Hornblende Schists.

INTRODUCTORY STATEMENT.

The granites and their associated differentiates, occupying about two-thirds of the area mapped, are confined to the eastern portion (see Pl. I). Similar rocks continue beyond the limits of the map and extend eastward for an unknown distance, for below the falls at Richmond they are covered by the later sediments of the Coastal Plain.

These rocks, while for the most part closely related, belong to several periods of intrusion, and vary in character and mineral composition within comparatively short distances. In composition they range from true granites, in which potash feldspars are dominant over plagioclase, through granodiorites and quartz-diorites, to rocks that are composed almost exclusively of hornblende—every gradation between the two extremes being found. Quartz is always present, the more acid rocks contain muscovite, and biotite usually occurs in all except the most basic varieties, where it is completely replaced by hornblende. With the appearance of hornblende in the rocks the potash feldspars disappear. The dominant rock type of the area corresponds to granodiorite or quartz-diorite in mineral composition. Pegmatites in places accompany the more acid facies, and pegmatitic quartz veins carrying a little mica are also present.

The large granite area occupying the eastern half of the map (see Pl. II) will be divided, for convenience in mapping and description, into

^aThis thin section was made from a specimen collected by Dr. J. S. Grasty.

4 separate divisions or belts, running in a northeast and southwest direction, in each of which the rocks exhibit certain peculiar characteristics. Passing from east to west these subdivisions are (1) the Cartersville area, (2) the Elk Hill complex, (3) the pegmatite belt, and (4) the Columbia area. In addition to these there are several smaller areas which occur within the boundaries of the pre-Cambrian sedimentaries, namely, the Gold Hill area lying between Kent's Store and Tabscott, the Rosney area near the southern border of the map, and an area of unknown but limited extent, in which the only exposures are at the Greeley mine. Each of these areas is described in detail below.

AGE.

The granites are younger than the pre-Cambrian rocks with which they are in contact, but the high degree of schistosity shown by most of the granites is proof of their solidification prior to the cessation of the great crustal movements that preceded the Cambrian. Evidence that the period covered by the intrusion and solidification of the granites continued until after the close of these great movements, is furnished by the fact that the last of the granites to crystallize are practically massive in texture. Similar evidence is furnished by the lack of schistosity in many of the pegmatites and aplites, which are residual differentiates from the granite magma, and are therefore of later crystallization.

Granites crystallize under conditions of deep burial, and therefore much overlying material must be removed by erosion before they are exposed. Near Carysbrook, Ordovician sediments may be seen resting on the eroded surface of almost massive granite, and this indicates that a considerable time interval must have elapsed between the solidification of the youngest granite and the deposition of the sediments in Ordovician time.

A consideration of the facts outlined above leads to the conclusion that the intrusion of the granites probably began during the pre-Cambrian and continued into the early Cambrian. It is not unlikely that the crustal movements which terminated the pre-Cambrian, and the intrusion of the granites, are both manifestations of the same general forces.

Cartersville Area.

GENERAL DESCRIPTION.

The Cartersville area occupies the southeast corner of the map (Pl. II) and its northwestern boundary, passing between Elk Hill and Pemberton, extends in a general southwesterly direction approximately parallel to and

just west of the ridge road leading from Cartersville to Cumberland. There are very few rock exposures in this area except in the vicinity of James River. The outcrops in the bluffs along James River and the occasional exposures found elsewhere indicate that the dominant rock is a fine-grained, light gray granite-gneiss, containing much muscovite and usually a little biotite. Pegmatites are common but the hornblende schists are extremely rare.

DETAILED DESCRIPTIONS.

Pemberton.—On the north side of James River, three-quarters of a mile southeast of Pemberton, there is a large outcrop of gneissic granite. The strike of the schistosity is nearly north and south and the dip about 45° east. There are two varieties of rock exposed at this point; one (Spec. 27) is the light gray muscovite granite which forms the dominant rock type in the Cartersville area; and the other (Spec. 28), underlying the first, is a highly schistose reddish-brown rock.

Examined megascopically, the light gray granite (Spec. 27) is fine-grained and composed of white feldspars, quartz, muscovite in flakes ranging up to 2 or 3 mm. in diameter, a little biotite in small black specks, and rarely small pink garnets. Under the microscope orthoclase feldspar is seen to be dominant over the soda-lime feldspar (probably oligoclase), and no microcline seems to be present; the muscovite is apparently primary; and the biotite is dark brown in color, and strongly pleochroic. Fine hair-like needles of rutile are very plentiful, occurring in feldspar, quartz, and muscovite, but they seem to be most abundant in the feldspars.

The dark-colored gneiss (Spec. 28), which underlies the rock described above, contains occasional lenticular eyes of feldspar and quartz. The rock has a peculiar reddish-brown (almost purple) color due to the presence of much fine-grained, brown biotite. In thin section under the microscope the soda-lime feldspars (probably oligoclase) are seen to be dominant, and there is only a little orthoclase and less microcline present. Some of the feldspars show zonal extinction. The biotite occurs in small light brown flakes and there is also some muscovite. Grains of ilmenite partly altered to leucoxene are common, and hair-like needles of rutile, sometimes curved, are occasionally present, being more numerous in the potash feldspars. A little pyrite and a few small grains of titanite make up the remaining accessory minerals.

A mile northwest of Pemberton, the granite exposed is nearly white in color and almost free of biotite. The minerals recognizable in the hand specimen (25) are white feldspar, quartz, and muscovite, a very

little biotite, and occasionally small pink garnets. Under the microscope the rock is seen to consist of irregular individuals of feldspar, quartz, and muscovite, ranging up to 1 mm. or over in diameter, which are surrounded by and grade into a finer ground-mass, composed largely of quartz and feldspar, and frequently granophyric in texture. Named in the order of their relative abundance, the mineral constituents are potash feldspar (chiefly microcline), quartz, soda-lime feldspar (probably oligoclase), muscovite, and a little biotite. The albite twinning in the plagioclase is very fine and sometimes absent. Around their border portions the feldspars frequently show graphic intergrowths with quartz. The muscovite is partly secondary after feldspar but most of it is probably primary. Only a little biotite is present, occurring in small dark brown flakes which are partly altered to chlorite. The quartz shows strain shadows and contains numerous fluid-filled cavities, some of which have moving bubbles.

Cartersville.—Fresh rock is exposed at a number of places in the vicinity of Muddy Creek and along the road a mile south of Cartersville. Most of it is the light gray muscovite granite, similar to Spec. 27, described above. In the road 200 yards southeast of Muddy Creek there is an outcrop of porphyritic granite. The rock (Spec. 473) contains numerous phenocrysts of white, unstriated feldspar ranging up to 1 cm. in diameter, and in places these feldspars constitute the greater part of the rock mass. They are surrounded by a fine-grained ground-mass of feldspar, quartz, biotite, and muscovite. A similar rock occurs on the opposite side of the river, about halfway between Pemberton and Stokes, where the feldspar phenocrysts range up to 5 or 6 cm. in diameter and are strung out in lines parallel to the schistosity. In some of the rock the large feldspars are so numerous that it resembles a pegmatite rather than a granite porphyry. The dominant rock in this vicinity, as elsewhere in the Cartersville area, is the light gray, muscovite granite. In places it contains pink garnets 0.5 cm. in diameter. At several points the dominant rock is cut by dikes of later granite, 2 or 3 feet in thickness. This later granite is fine-grained, less schistose, and contains more biotite and less muscovite.

Stokes.—One of the few places in the Cartersville area where hornblende rocks occur is located above three-quarters of a mile west of Stokes. At this point there is a small outcrop of fine-grained, even-granular schist, showing slightly gneissic banding, and composed essentially of quartz, feldspar, black hornblende, and epidote. The surrounding rock is chiefly a muscovite granite with occasional outcrops of pegmatite.



Fig. 1.—Flow structure in banded gneiss intruded between layers of hornblende schist.

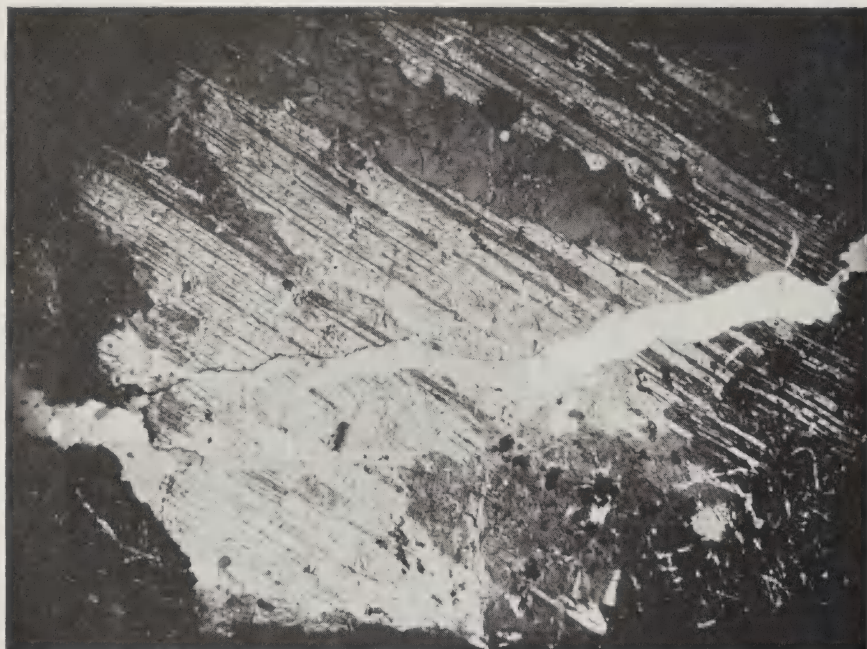


Fig. 2.—Photomicrograph of plagioclase feldspar in vein quartz from the Waller mine. With analyzer. Magnified 27 diameters. See page 149. Specimen No. 217.

FLOW STRUCTURE AND PLAGIOCLASE FELDSPAR.

Elk Hill Complex.

GENERAL DESCRIPTION.

The Elk Hill complex is made up of three principal rock types—biotite granite, hornblende schist, and pegmatite—which occur interleaved in layers of varying thickness and in places are much contorted. The hornblende rock appears to have been formed first and the granite intruded into it later, while the pegmatite frequently cuts both of the other rocks. The complex is from one to $1\frac{1}{2}$ miles wide where it crosses James River at Elk Hill, and the best exposures are found in the bluffs three-quarters of a mile below Elk Hill. There are exposures along the road $1\frac{1}{2}$ to 2 miles east of Flanagan Mills, and also in the road just southeast of Fife, but at neither of these localities is it possible to obtain fresh material.

DETAILED DESCRIPTIONS.

Excellent outcrops of fresh rock occur along the bluffs, three-quarters of a mile southeast of Elk Hill, where much blasting was done to make room for the old James River canal. In the photograph shown in Pl. VIII, fig. 1, the straight dark bands are hornblende schist, while the light-colored layers consist of biotite granite and pegmatite. The contortions seen in the layer or dike of granite, which occupies the center of the photograph, probably represent flow structure, for if they were formed by crustal movements occurring after the complete solidification of the rock the layers of hornblende schist would likewise have been affected. The light-colored bands in the granite are pegmatitic in character. Elsewhere in the immediate vicinity the granite may be seen cutting across the hornblende rock while the veinlets of pegmatite sometimes stop short at the contact and sometimes cut across both rocks.

The hornblende schist (Spec. 22) is dark gray to nearly black in color, and is composed of black hornblende, in crystals ranging up to 2 or 3 mm. in length, white feldspar, and a little black biotite. Small grains of pink garnet can be identified in places. The rock is cut by narrow, irregular veinlets of white feldspar and quartz, and contains lenticular eyes of feldspar 2 cm. and less in diameter. Occasionally a little fine multiple twinning can be distinguished on these feldspars. Under the microscope the hornblende shows perfect cleavage and is pleochroic in shades of light green, greenish-blue, and brown. The feldspars are plagioclase (probably oligoclase) and sometimes show zonal growth; multiple twinning is very fine when present and is frequently absent. There is also

present a little quartz, occasional ragged prisms of tourmaline, numerous rounded grains of titanite, and a little epidote. The thin section is crossed by several microscopic fractures, which branch in places and are filled chiefly with quartz and feldspar.

The granite (Specs. 21 and 23) is a light gray, fine-grained rock, composed essentially of white feldspar, quartz, and a little black biotite, while small pink garnets can be identified in places. It is cut by occasional, irregular, segregation stringers of pegmatitic feldspar and quartz. Fine multiple twinning can sometimes be distinguished on the feldspars. In thin sections under the microscope, soda-lime feldspar is seen to be dominant with the potash feldspars (orthoclase and microcline) present in variable amounts; there are granophyric intergrowths of feldspar and quartz; and both the feldspar and quartz show fracturing and optical distortion. Biotite occurs in small flakes dark green to brown in color, and a little sericite is present as an alteration product of feldspar. Ragged prisms of tourmaline, and occasionally irregular grains of titanite, magnetite, and pyrite make up the accessory minerals. The quartz grains contain numerous fluid inclusions.

In mineral composition this rock corresponds to a granodiorite and is closely similar to the granite (granodiorite) exposed in the quarry at Columbia, an analysis of which is given on page 65. The Elk Hill granite is finer grained and probably contains less quartz than the rock at Columbia.

Passing northeast toward Elk Hill the granite bands become broader, less contorted, and more uniform in composition; and there is much less hornblende schist present. Near Elk Hill the schistosity has a strike of N. 45° E. and a dip of about 45° southeast. The granite exposed near Byrd Creek is similar to that in the Columbia area on the west side of the pegmatite belt.

In places the hornblende schist contains much epidote, and about a mile southeast of Elk Hill some of the rock is composed almost exclusively of light green, granular epidote and white feldspar. In a thin section of this rock (Spec. 26), examined under the microscope, the epidote is largely in excess, occurring in irregular rounded grains, that look as though they might be primary. It is slightly pleochroic, changing from light yellowish-green to colorless. The feldspars are partly kaolinized but are probably all plagioclase. A little quartz and a few small grains of ilmenite, partly altered to leucoxene, make up the remaining minerals present.

Pegmatite Belt.

GENERAL DESCRIPTION.

The pegmatite belt can be traced across the area mapped, in a north-east and southwest direction, from Hadensville in Goochland County, to Cumberland, near the southern boundary—a distance of over 30 miles—and it extends for an unknown distance beyond the limits of the map. In width the belt varies up to nearly three miles, and perhaps more, for lack of exposure makes it difficult to locate the exact boundaries except in a few localities.

While pegmatite is the dominant rock in this belt, there is also much interleaved granite, especially along the eastern side. North of James River, where the area was mapped in detail, the northwest contact of the pegmatite with the granite is sharply defined, but the other boundary is less definite, for the pegmatite apparently fingers out into the granite; and in many places the two rocks are so closely associated that it would be impossible to map them as separate units. In most of the specimens of granite obtained from the central portion of the pegmatite area, and examined microscopically, the potash feldspars are dominant over the soda-lime feldspars. Hornblende schists are practically absent; no outcrops were seen, and the few pieces of float found were near the border portions.

The pegmatite area is one of low relief and there are few prominent outcrops. It seems to be less resistant to erosion than the granite, and this probably explains the location of Little Byrd Creek, which, throughout almost its entire length, is confined to the pegmatite belt.

DETAILED DESCRIPTIONS.

James River section.—The best rock exposures found in the pegmatite belt occur along the steep hills and bluffs that border the lowlands on the north side of James River. The railroad station at Island is near the center of the belt, which is here about 3 miles wide. The western boundary crosses the river midway between Columbia and Island, and is sharply defined; but the eastern boundary, which crosses the river near Byrd Creek, is less definite, for the pegmatite is more or less interleaved with biotite granite and the exposures are rather poor.

Near the western boundary of the pegmatite belt, $1\frac{1}{4}$ miles northwest of Island, there are outcrops of coarsely crystalline pegmatite (Spec. 12-A) composed of pink orthoclase feldspar, quartz, and a little muscovite. The

feldspar, which is dominant, occurs in irregular individuals ranging up to 2 or 3 inches in diameter. The rock is slightly gneissic in structure, the strike of the schistosity being northeast and southwest and the dip nearly vertical.

In places the coarse pegmatite is interleaved with a fine-grained pegmatite or granite (Spec. 12), similar in composition, and highly schistose. Examined under the microscope it is seen to be granitic in texture with occasional fine micrographic intergrowths of quartz and feldspar. Microcline is the dominant mineral, orthoclase being also present, while quartz and acid plagioclase feldspars occur in lesser quantities. The feldspars frequently show perthitic intergrowths and are partly kaolinized; the quartz contains irregular fluid inclusions, which occasionally hold moving bubbles; and both minerals have been more or less fractured and show some optical distortion. The muscovite is partly if not entirely secondary after feldspar. Magnetite, ilmenite partly altered to leucoxene, and titanite make up the minor accessory minerals.

A coarse-grained, gneissic pegmatite, which outcrops half a mile west of Island, contains numerous red garnets, 1 to 2 mm. in diameter; otherwise it is similar to the rock previously described. In the vicinity of Island there is much biotite granite intermixed with the pegmatite.

Little Byrd Creek.—For several hundred yards east of Little Byrd Creek, and about $2\frac{1}{2}$ miles northeast of Island, the road to Fife is crossed by alternating bands of pegmatite and granite, which vary in width from an inch up to several feet. The average strike is N. 45° E. The pegmatite (Spec. 71) is composed of pink potash feldspar, in individuals ranging up to 3 inches in diameter, quartz, a little muscovite, and a few dark red garnets, some of which are over half an inch in diameter. In places a graphic intergrowth of quartz and feldspar may be distinguished. Farther east the bands are somewhat contorted.

Where the large branch crosses the road, half a mile west of Little Byrd Creek, a dark brown, fine-grained granite is exposed. It is about 50 yards wide and has a strike of N. 45° E. The rock (Spec. 70) is fine-grained, even-granular, except for occasional phenocrysts of potash feldspar about 0.5 cm. in diameter, and is only slightly schistose. Examined under the microscope it is seen to consist of potash feldspar (chiefly orthoclase), soda-lime feldspar, quartz, biotite, muscovite, a little light brown hornblende, a few scattered grains of magnetite or ilmenite, and occasional needle-like inclusions of rutile. The feldspar individuals, near their borders, frequently show granophyric intergrowths with quartz. The

quartz grains contain numerous fluid inclusions, some of which hold rapidly moving bubbles. Both quartz and feldspar show fracturing and optical distortion. The muscovite is partly secondary after feldspar but some of it is probably primary.

Lantana.—The contact between the pegmatite and granite crosses the road to Bula, $1\frac{1}{8}$ miles southeast of Lantana. The outcrops are much weathered but in places graphic intergrowths of feldspar and quartz can be seen. The pegmatite weathers to a white soil which is readily distinguished from the gray, sandy soil of the granite and the dark red clay of the hornblende schist.

Bula.—On the east side of the pegmatite belt, in the vicinity of Bula, the boundary is not very definite, for the pegmatite splits up into dikes that are separated by areas of granite. One of these dikes is located about half a mile southeast of Bula, and can be traced in a northeast and southwest direction for a mile or more. This pegmatite (Spec. 77) contains a large amount of muscovite mica, and flakes 2 or 3 inches in diameter are sometimes found on the surface.

Shannon Hill.—The western boundary of the pegmatite belt crosses the Three Chop road about $2\frac{1}{2}$ miles southeast of Shannon Hill. There are practically no outcrops along this ridge road, but an exposure of partly decomposed pegmatite was found in a recently opened ditch. The rock is a beautiful example of graphic pegmatite, being composed almost exclusively of feldspar and quartz, and shows little if any schistosity.

Dickey farm.—On the farm of G. S. Dickey, 2 miles southeast of Cremona, there are several pits that were sunk in prospecting for gold. Natural exposures are few in this vicinity, but the country rock is partly a dark granite similar to Spec. 70, described on page 60. In the pits a dark blue, close-textured, siliceous rock is exposed, which appears to have been formed by silicification of the country rock, for it contains fragments of the granite that are only partly replaced by silica. The rock is extensively brecciated and has been recemented by white vein quartz. There are numerous vugs lined with quartz crystals and many of the veinlets show crustification. The minerals sphalerite, pyrite, chalcopyrite, and galena, are present in small amounts and may be identified in places; and assays are reported to show traces of gold and silver. The ore minerals, at least in part, appear to be of later deposition than most of the quartz; in one specimen, sphalerite occurs filling a small cavity which is lined with quartz crystals.

Other localities.—Pegmatite is exposed at many places in Cumberland County along the strike of the pegmatite belt, but outcrops of fresh rock are rare, and all that were examined in detail show little variation from the occurrences described above. Pegmatite is exposed near Willis River, for a mile or two southwest of Flanagan Mills; it outcrops near Reynolds Creek, about 2 miles southeast of Trenton Mills, and again between Tally and Oak Forest; and there are numerous exposures in the vicinity of Cumberland, and near the southern boundary of the area mapped.

Columbia Area.

GENERAL DESCRIPTION.

The Columbia granite area is bounded on the northwest by the metamorphosed sedimentaries, chiefly pre-Cambrian in age, and on the southeast by the pegmatite belt; but much of the granite that occurs interleaved with the pegmatite and in the Elk Hill complex appears to be similar in mineral composition to the typical granite of the Columbia area, and probably has a common origin.

In the Columbian area there is very little rock present corresponding in mineral composition to a true granite, in which orthoclase is dominant over the plagioclase feldspar. Almost everywhere soda-lime feldspars are in excess, and near the border portion of the rock and close to many of the areas of hornblende schist, the potash feldspars are entirely absent. Therefore the rock may more properly be called a granodiorite or quartz-diorite. Muscovite is not common; biotite is usually plentiful in the dominant and more acid facies of the rock, but in the southern portion of the area it is largely replaced by hornblende.

Hornblende schists are of frequent occurrence in all portions of the area except in the north end of the tongue or embayment lying between Carysbrook and Wilmington; they become more plentiful near the contact with the old metamorphosed sedimentaries, where they commonly form a narrow belt separating the granite from the older rocks. In some places a gradation may be traced from granite into hornblende schist, but frequently the contact between the two is sharply defined. The areas of hornblende schist vary in size from a maximum of several square miles down to small masses, such as are usually called *schlieren*.

In passing northward from James River toward Carysbrook and Wilmington, there is a gradual but very noticeable change, both in the mineral composition and in the texture of the rock. While the exposures

are by no means continuous, outcrops are fairly plentiful along the bluffs of Rivanna River, and nowhere is there any evidence of sudden change such as would be expected if there were rocks present belonging to different periods of intrusion.

South of James River, soda-lime feldspars greatly predominate over the potash feldspars, which are frequently absent; most of the rock is hornblendic rather than biotitic; and the areas of hornblende schist are common. Passing northward toward Carysbrook the potash feldspars become more abundant though they are usually subordinate to the plagioclase; hornblende is rarely present in the granite, while biotite which is plentiful near the river becomes relatively scarce; and no areas of hornblende schist were found northwest of Rivanna Mills. The change is therefore one of decreasing basicity, and of decreasing percentages of the minerals that commonly crystallize out first.

In the vicinity of James River the granites are even-granular in texture but passing northward they become porphyritic and contain phenocrysts of feldspar. These phenocrysts are frequently bent and broken, the fractures as well as the interstitial spaces being filled with minerals of later crystallization; and this indicates that differential movements took place in the magma after crystallization had commenced and before the rock had completely solidified. The occurrence of masses of coarse-grained granite surrounded by rock of finer texture, such as may be seen in the quarry a mile northwest of Carysbrook (see description, pages 75-77), is probably due to the same causes.

The granite south of James River is highly schistose; the rocks exposed in the vicinity of Fork Union and Rivanna Mills are much less affected, while north of Carysbrook the granite is almost massive.

Pegmatite dikes are plentiful near Rivanna Mills, but were not noted elsewhere in the Columbia area. These pegmatites show little or no evidence of schistosity.

All of the facts outlined above lead to the same conclusions, namely, that the granite in the north end of the embayment between Carysbrook and Wilmington solidified later than the rock in the remainder of the area; that important differential movements took place while this later granite was in process of crystallizing; and that the magma from which the latter solidified was probably residual from the crystallization of the older rocks.

DETAILED DESCRIPTIONS.

Columbia.—The Cowherd quarries,^a located on the north side of James River at Columbia, and lying partly in Goochland County and partly in Fluvanna County, furnish the best exposures of fresh granite that are to be found in the Columbia area. These quarries were first opened when the James River canal was in service, but in recent years little work has been carried on, and since 1900 all operations have been suspended.

The rock is of medium dark-gray color, fine-grained, even-granular, and very schistose, with fine, straight banding. The minerals distinguishable megascopically are white, glassy quartz and feldspar, black biotite, a few, light green grains of epidote, which are for the most part closely associated with the biotite, and occasional small pink garnets. Multiple twinning can be distinguished on some of the feldspars with the aid of a pocket lens.

The strike of the schistosity is N. 45° E. The vertical joints are widely spaced, intersecting the rock in three or more directions, and the joints parallel to the surface are spaced 2 to 3 feet apart in some of the deeper exposures. The granite is cut by numerous quartz veins which usually carry a little biotite. They vary from a fraction of an inch up to 2 feet in width, and run in all directions, though most of them are probably parallel to the schistosity. The fact that fractures frequently intersect the veins in directions coincident with the schistosity indicates that they were formed before the cessation of the period of deformation.^b The presence of biotite and, occasionally, of a little muscovite and feldspar, are additional evidence of the early formations of the veinlets and of their probable magmatic origin.

Examined in thin section (Spec. 240) under the microscope the rock is seen to be composed of the following minerals, the order given being that of relative abundance—quartz, soda-lime feldspar (oligoclase), potash feldspars (chiefly microcline), biotite, muscovite, epidote, garnet, calcite, zircon, and apatite. Under low magnification the schistosity is distinct; most of the mica shows parallel orientation and the segregation of the quartz into bands is so pronounced that in places they resemble veinlets. This fact suggests that some of the quartz veinlets exposed in the quarry may have been formed by segregation through fractional crystallization during the solidification of the granite.

^aWatson, Thomas L., *Granites of the Southeastern Atlantic States*, Bull. U. S. Geol. Survey, No. 426, 1910, pp. 112-113.

^bWatson, Thomas L., *Ibid.*, p. 113.

The quartz is present in large clear individuals that in places show a slightly wavy extinction; liquid- and gas-filled cavities are common, occurring partly in irregular shapes, and partly in small oval or rounded forms that are arranged in long rows or planes.

The soda-lime feldspar, which is dominant over the potash feldspars, shows rather coarse twinning after the albite law; the potash feldspar is nearly all microcline and there is only a little orthoclase present. Granophyric intergrowths of feldspar and quartz are fairly plentiful.

Biotite occurs in small dark green flakes showing strong absorption, and the white mica present is partly if not entirely secondary after feldspar. The epidote is in small, irregular light green to colorless grains, which are more plentiful wherever the biotite is abundant and are absent in areas containing little biotite.

Small pink garnets are scattered through the thin section; they are frequently fractured and broken, and seldom show good crystal form. The small amount of calcite present is evidently secondary. Numerous small idiomorphic crystals of zircon, and occasional apatite needles, are present as inclusions in the quartz and feldspar.

In mineral composition the rock is intermediate between granite and quartz-diorite. In the quantitative system of classification of igneous rocks it falls in class 1, order 3, rang 3, and subrang 4. A complete chemical analysis made from an average sample of the granite exposed in the quarry is given below.

Analysis of granite from Cowherd quarry, Columbia.

(Dr. Roger C. Wells, analyst.)

SiO ₂	72.43
Al ₂ O ₃	13.93
Fe ₂ O ₃	0.90
FeO	2.45
MgO	0.58
CaO	3.38
Na ₂ O	3.20
K ₂ O	2.14
H ₂ O—	0.11
H ₂ O+	0.54
TiO ₂	0.21
ZrO ₂	.....
CO ₂	0.09
P ₂ O ₅	0.04
S	0.01
MnO	0.02
BaO	0.01
SrO	Trace
Li ₂ O	Trace
	100.04

About a quarter of a mile northwest of the quarries described above, and on the east side of the Stage Junction road as it leaves Columbia, a fresh surface of granite is exposed by recent blasting. The rock is cut by irregular veinlets of quartz some of which contain biotite mica; and there are also veinlets of coarsely crystalline calcite ranging up to 2 inches in width.

Megascopically the rock (Spec. 5) is similar to the granite described above, excepting that the gneissic banding is slightly more prominent. Under the microscope the chief difference is in the relative proportion of the feldspars, orthoclase and microcline being present in very subordinate amounts. White mica is practically absent and there is a little hornblende present, dark green to bright blue in color. Ilmenite, partly altered to leucoxene, occurs as a minor accessory constituent.

Passing northward along the Stage Junction road bands of hornblende schist begin to make their appearance at a distance of half a mile from Columbia. At first these bands or schlieren are only a few feet wide, but, as the contact with the sedimentaries is approached, they become larger and more plentiful until, within 400 or 500 yards of the contact, the granite completely disappears. There is also a change in the direction of the schistosity; near Columbia it has a strike of approximately N. 45° E., but near the sedimentaries the schistosity runs N. 15° W., and appears to be parallel to the contact. These areas of hornblende rocks occur throughout most of the Columbia granite area, but they are much more plentiful in the vicinity of the borders.

About 1¼ miles east of Columbia there is a large rock exposure showing a gradation of the granite into hornblende schist. The schistosity varies from N. 20° to 40° E. The belt of hornblende schist is elongated parallel to the schistosity—the width being about 200 feet, and the length indeterminable because of the lack of sufficient exposures.

Specimen 6, taken more than 100 feet west of the belt of schist, is intermediate in character, but in the hand specimen is almost indistinguishable from the typical Columbia granite. The rock is dark gray in color, fine-grained, and shows a well-developed gneissic banding. It is composed essentially of quartz, feldspar, biotite, black hornblende, which is very difficult to distinguish megascopically from the biotite, small pink garnets, and a little epidote.

Examined under the microscope, soda-lime feldspar seems to be dominant over quartz, the potash feldspars are absent, and the hornblende is equal to or in excess of biotite. The feldspar frequently shows twinning

according to the pericline as well as the albite law; the quartz contains numerous fluid inclusions arranged in long lines or planes; and the hornblende is brown to dark green in color, and shows occasional idiomorphic outlines with perfect cleavage. Small, well-formed, pink garnets, a few grains of light green to colorless epidote, and, rarely, small idiomorphic crystals of zircon make up the minor accessory minerals.

Specimen 7 was taken from the outcrop about 30 feet northeast of the rock just described. It is finer grained than specimen 6, and contains more hornblende, much of which is concentrated in narrow streaks or schlieren. Under the microscope, plagioclase feldspar is seen to be dominant over quartz, and there is no potash feldspar or white mica present. The feldspars show twinning after the pericline as well as the albite law, and some of them contain peculiar inclusions of feldspar or quartz, which are present in alternate bands of the albite twinning. These inclusions are in the form of narrow parallel bands, which are oriented at an angle of 30° to the twinning planes, and they all extinguish simultaneously. The hornblende is strongly pleochroic in shades of dark green, blue, and greenish-brown. The biotite is light brown to green in color and is not nearly so plentiful as the hornblende. Garnet in fairly well formed crystals, irregular grains of epidote, ilmenite, and small inclusions of zircon make up the minor constituents.

About 110 feet east of the specimen just described, the rock (Spec. 8) contains flat, bladed crystals of black hornblende, ranging up to 1 cm. in length, embedded in a medium-grained ground-mass of feldspar and quartz. With increase of hornblende there is a corresponding decrease of biotite, and portions of the rock are almost free of mica. The garnets are likewise larger in this rock, some of them being nearly 0.5 cm. in diameter. The larger size of some of the minerals, especially the hornblende, may have been caused by a partial resolution before complete solidification had taken place, followed by continued crystal growth.

Microscopically, soda-lime feldspar is the dominant mineral and there is no potash feldspar or white mica present. Both albite and pericline twinning are common. Quartz is the second mineral in relative abundance and contains numerous irregular fluid-filled cavities. Dark green hornblende is the principal ferromagnesian mineral, only a little brown biotite being present. The remaining accessory minerals are garnet, in numerous well-formed crystals, epidote, ilmenite partly altered to leucoxene, pyrite partly altered to limonite, and small included grains of titanite and zircon.

Specimen 9, taken from a point 30 feet southeast of the rock last described, is a typical quartz-diorite schist. It is a dark gray, medium-

grained rock in which black hornblende, and white quartz, and feldspar are the only minerals distinguishable megascopically. Under the microscope plagioclase (probably andesine) is seen to be dominant, but dark green hornblende is almost as abundant as the feldspar. Quartz, a little epidote, and a few small, scattered grains of ilmenite make up the remaining constituents. Both quartz and feldspar show considerable optical distortion and some fracturing.

Specimen 10 was taken 80 feet farther northeast. Megascopically it is similar to specimen 9, but contains more hornblende and is darker colored, being almost black. Examined microscopically no feldspar could be distinguished. The minerals present in the order of their relative abundance are hornblende, quartz, epidote, chlorite, and a few scattered grains of ilmenite.

About 100 feet to the east there is an outcrop of greenish-gray, talcose schist, which probably represents an alteration product of the amphibolite schist described above. In thin section (Spec. 11) under the microscope, the rock is seen to consist of needle-like crystals of secondary hornblende, light green to almost colorless talc, a little chlorite, and numerous small grains of magnetite.

Near the large creek 2 miles southwest of Columbia there is much quartz lying loose on the surface and these pieces contain much muscovite, and occasionally miarolitic cavities lined with poorly formed crystals of quartz, feldspar, and muscovite. Some of the mica shows well-developed hexagonal shapes.

On the road to Lantana, hornblende schists are first encountered about half a mile northeast of Columbia, and, continuing northeastward, the occurrences increase in number and extent, until in the vicinity of the contact, little granite is to be found. The contacts between the areas of hornblende schist and the granite are commonly sharp and well defined, but in many places rocks occur that are intermediate in mineral composition.

Big Byrd Creek.—On the east side of Big Byrd Creek, near the contact between the granitic rocks and the altered sedimentaries, there is an outcrop of rock which is intermediate between the granite and the typical hornblende schists.

It is a dark gray, fine-grained gneiss (Spec. 29) composed essentially of feldspar, hornblende, quartz, and biotite. Examined microscopically the feldspar is seen to be all plagioclase; multiple twinning is frequently absent, and as the index of refraction is close to that of quartz, there is

difficulty in distinguishing between the two minerals. The hornblende crystals are strongly pleochroic, ragged in outline, and contain numerous inclusions of quartz, feldspar, and epidote. The biotite, which is partly altered to chlorite, is not plentiful. Ilmenite occurs in irregular grains scattered through the rock, and shows partial alteration to leucoxene.

Lantana.—A peculiar variety of the hornblende schist was found about $1\frac{1}{4}$ miles southeast of Lantana. The minerals recognizable megascopically are black hornblende and a little fine-grained, white feldspar. The hornblende crystals are frequently stained a deep red color, and the contrast between the black, red, and white gives the rock a very striking appearance in the hand specimen (93). Examined microscopically it is seen to consist of hornblende, basic plagioclase, epidote, quartz, magnetite partly altered to limonite, and a few small grains of rutile.

About $2\frac{1}{2}$ miles northeast of Lantana the pegmatite belt approaches within less than 400 yards of the altered sedimentaries, and the intervening space is largely occupied by hornblende schists. At this point the biotite granite is absent, being replaced by a hornblende-bearing rock (Spec. 99), which closely resembles a granite in appearance, but contains no potash feldspar. It is a medium, dark gray, gneissic rock, composed of quartz, acid plagioclase, hornblende, and garnet, with lesser amounts of magnetite, zircon, and titanite. Some of the feldspar is unstriated and difficult to distinguish microscopically from quartz, which it resembles in refraction and birefringence. The hornblende is dark green to bluish-green in color, strongly pleochroic, and shows fairly good cleavage. Pink garnets are very plentiful, and the larger ones contain numerous inclusions of quartz and magnetite.

Passing northeast from the locality just described, the lack of exposures makes it difficult to trace the exact contact between the granite area and the metamorphosed sedimentaries; and this difficulty is increased by the uncertainty as to the igneous or sedimentary origin of some of the rocks in the immediate vicinity of the contact.

Granite is exposed in the branch near the private road, less than a mile northeast of the Young American mine. It is a light gray, fine-grained rock (Spec. 105), composed chiefly of quartz and feldspar, with minor amounts of biotite. Under the microscope the feldspar is seen to be plagioclase (probably andesine), but, as much of it is unstriated, it is distinguishable from quartz with difficulty. The rock contains a little sericite, ilmenite partly altered to leucoxene, and occasional small inclusions of rutile, titanite, and zircon.

Tabscott.—Granite and hornblende schist outcrop together near the branch half a mile northeast of the locality last described and about $1\frac{3}{4}$ miles south of Tabscott. The granite (Spec. 108) is a light gray, fine-grained rock, gneissic in structure, and composed for the most part of quartz, feldspar, and small flakes of light green chlorite. Examined microscopically the feldspars are seen to be chiefly acid plagioclase, with only a little orthoclase present; granophyric intergrowths with quartz are common; and in places the feldspars show alteration to sericite. Ilmenite occurs in small grains that usually show alteration to titanite or leucoxene. The alteration to titanite is more common and there are many grains of the latter scattered through the rock.

The hornblende schist (Spec. 109) is dark bluish-gray in color, and usually fine-grained. The hornblende, which is dominant, occurs in slender, prismatic crystals, that are dark green in thin sections, and frequently show idiomorphic outlines and perfect cleavage. Quartz and unstriated plagioclase feldspar (probably andesine) fill the interstices between the hornblendes. Ilmenite and rutile are prominent accessory constituents, occurring as included grains in all of the other minerals, though they are not so plentiful in the hornblende. There are also numerous grains of titanite present, probably secondary after the other titanium minerals, and small crystals of zircon occur as inclusions in the quartz.

A similar, but slightly coarser-grained, hornblende schist outcrops in the road $1\frac{1}{2}$ miles southwest of Tabscott. The rock (Spec. 215) is composed of hornblende, quartz, unstriated plagioclase (oligoclase or andesine), a little epidote, and numerous grains of titanite, some of which contain small inclusions of rutile. In these schists the hornblende crystals have a strong tendency to lie with their columnar directions almost parallel, and it is this that gives the rock its schistosity. The strike of the schistosity is N. 51° E.

Payne farm.—On the Payne farm, $1\frac{1}{2}$ miles southeast of Tabscott, there is a number of old pits or quarries from which the Indians obtained steatite. These openings are surrounded by pieces of broken bowls which were ruined in the process of making. Recently, sawed slabs of this rock have been used to line the fire boxes of boilers, at some of the mines in the vicinity, and it is said to have proved very satisfactory for the purpose.

The rock (Spec. 107) is greenish-gray in color and in places contains small crystals of magnetite and pyrite. Under the microscope it is seen to consist largely of talc and needle-like crystals of secondary hornblende. There are also a few fragments of unaltered hornblende which may be primary,

much chlorite, and a little magnetite or ilmenite, and titanite. The rock is evidently derived from a basic igneous rock, probably from the hornblende schists. A similar occurrence is described on page 68.

Some of the rock in this vicinity contains a greater percentage of hornblende than the specimen described above, and other pieces were found that consist exclusively of bright green cleavable chlorite.

Trent farm.—On the south side of James River, in the southern portion of the Columbia area, the rocks are apparently more basic in composition, potash feldspars are practically absent and hornblende is often more prominent than biotite. On the farm of S. W. Trent, 3 miles southwest of Hatcher, hornblende schist occurs in the vicinity of the contact. The rock is dark gray to black in color, with a highly lustrous fracture, due to the presence of much hornblende having approximately parallel orientation. The minerals present, in the order of their relative abundance, are prismatic hornblende, feldspar, quartz, and a little epidote. The feldspar is all plagioclase, corresponding to labradorite in extinction angle and index of refraction, and much of it is unstriated.

Passing northwest as far as Hatcher, hornblende is a prominent constituent in most of the rocks found; in places it is dominant over the other minerals, forming the typical hornblende schists, but elsewhere feldspar is dominant, and the rocks correspond to diorites and quartz-diorites in composition. On the whole hornblende appears to decrease in abundance with distance from the contact. The same statement holds true for the rocks that are exposed between Lawford and the contact.

Trenton Mills.—On the west side of Willis River, in the vicinity of Trenton Mills, there is a large area of hornblende schist, possibly 2 or 3 square miles in extent. The rock is medium-grained and highly schistose, the color varying from gray to black according to the amount of feldspar and quartz present. The darker varieties are composed almost exclusively of hornblende.

New Canton.—In some of the branches 3 or 4 miles south of New Canton a hornblende granite or quartz diorite is exposed, which contains a few large flakes of dark brown biotite and small pink garnets. A short distance east of the county road and $1\frac{3}{4}$ miles south of New Canton a light gray, gneissic rock (Spec. 300) is exposed which consists essentially of feldspar, quartz, biotite, and muscovite.

Examined under the microscope no potash feldspar could be identified. The plagioclase has an index of refraction slightly below quartz, approximately corresponding to oligoclase in composition, and frequently shows

twinning after the albite and pericline laws, but much of it is unstriated. The biotite is brown to green in color and the muscovite is partly if not entirely secondary in origin. A little chlorite and epidote are present, but other accessories are rare.

Stearnes.—Near the Chesapeake and Ohio Railroad, 2 miles northeast of Stearnes and 4 miles southwest of Columbia, the granite (Spec. 14) is light gray, fine-grained, and shows distinct gneissic banding. Occasional phenocrysts of feldspar showing Carlsbad twinning can be distinguished in the hand specimen. This is one of the few localities in the Columbia area where the rock is a true granite in mineral composition. The minerals present, in the order of their relative abundance, are potash feldspar (chiefly microcline), soda-lime feldspar (oligoclase), and quartz; a little biotite, muscovite, calcite, and epidote; and lesser amounts of garnet, titanite, ilmenite, leucoxene, and zircon.

Microcline showing beautiful crossed twinning is the dominant mineral and orthoclase seems to be practically absent. Oligoclase, which is the second mineral in relative abundance, shows occasional twinning after the pericline as well as the albite law, and micropertthite is fairly plentiful. Micrographic intergrowths with quartz are common. The biotite is dark green to brown in color and not very abundant; the flakes are usually oriented parallel to the schistosity of the rock. The white mica appears to be entirely secondary after feldspar, but there may be some primary muscovite present. It does not show the same uniformity of orientation that is exhibited by the biotite. Calcite is unusually abundant and is probably secondary after plagioclase. Epidote occurs in small grains, being more plentiful where the biotite is most abundant, and is undoubtedly secondary in origin. The garnets contain numerous small inclusions of quartz. Titanite is common and in places contains included grains of ilmenite, from which it may have been derived. The ilmenite grains occasionally show partial alteration to leucoxene.

For a mile northeast of Stearnes hornblende schist is exposed in the bluffs along the railroad. It is a fine-grained, dark bluish-gray rock, composed of small black prismatic crystals of hornblende, showing approximate parallel orientation, and white plagioclase and quartz. The contact with the granite on the northwest side of the schist is well exposed. It is sharply defined, without evidence of gradation, and has a strike of N. 45° E.

Near Stearnes the hornblende schist is cut by narrow bands of siliceous rock 2 to 3 inches in thickness. This rock (Spec. 16) is fine-grained,

light gray in color, and closely resembles a quartzite in texture and appearance. Small pink garnets and needles of dark green hornblende are present in places, and some of the rock contains much fine-grained magnetite. A thin section examined under the microscope contains irregular rounded grains of quartz, many idiomorphic crystals of magnetite, a few scattered prisms of dark green hornblende showing occasional crystal outlines, a little plagioclase feldspar, sericite, and small inclusions of titanite and zircon. The quartz contains numerous fluid inclusions.

Fork Union.—The contact between the granite and the metamorphosed, pre-Cambrian sedimentaries passes through the town of Fork Union. Granite is exposed in the road about half a mile southeast of the town. It is a medium-grained, light gray rock, containing flakes of biotite 2 to 3 mm. in diameter, and is much less schistose than the rocks previously described.

Examined in thin section (Spec. 50)^a under the microscope, potash feldspar (chiefly microcline) appears to be dominant over soda-lime feldspar, but the rock is so badly altered that it is impossible to determine their relative proportions. Micrographic intergrowths with quartz are common. Both quartz and feldspar show fracturing and strain shadows. The biotite occurs in greenish-brown flakes showing strong absorption. The feldspars and biotite are extensively altered with the production of epidote, a little chlorite, and some sericite, as the principal secondary minerals. Reddish-brown prisms of tourmaline 1.5 mm. or more in length are occasionally present, and rutile needles are abundant especially in some of the biotite. Fluid inclusions are common in the quartz grains.

A similar granite, occurring at the Snead mine a mile north of Fork Union, is described on page 181.

Rivanna Mills.—On the farm of H. Williams, half a mile north of Rivanna Mills, granite was formerly quarried to furnish stone for the dam and canal locks. This rock is medium dark gray in color and porphyritic in texture, containing eyes of feldspar that range up to nearly 1 cm. in diameter. The minerals recognizable megascopically are feldspar, quartz, biotite, a little muscovite, and, rarely, small grains of pyrite. Some of the feldspar phenocrysts show fine multiple twinning. The schistosity is well developed, but is not nearly so pronounced as in the granites exposed in the section along James River.

^aThis thin section was made from a specimen collected by Dr. T. P. Maynard.

An average sample of partly decomposed granite, from an outcrop 100 yards east of Mr. Williams' house, upon assaying yielded 0.015 ounces of gold per ton (see pp. 220-221). The sample was taken after several inches of the partly decomposed rock had been removed in order to prevent contamination.

Dikes of pegmatite and aplite occur cutting the granite at several points on the Williams farm, and these rocks show very little if any evidence of schistosity. One of these dikes, located about 600 yards northeast of the house, is exposed in a prospect shaft 15 feet in depth. It has a strike of N. 15° E. and dips northwest at an angle of 45°. The pegmatite near the walls of the dike (see fig. 3) is fine-grained, and composed for the most part of feldspar and quartz, with only a little muscovite. The central portion of the dike consists chiefly of quartz carrying more or less feldspar and containing occasional coarse crystals of pyrite. Picked specimens of this quartz are said to have assayed nearly \$3.00 gold per ton.

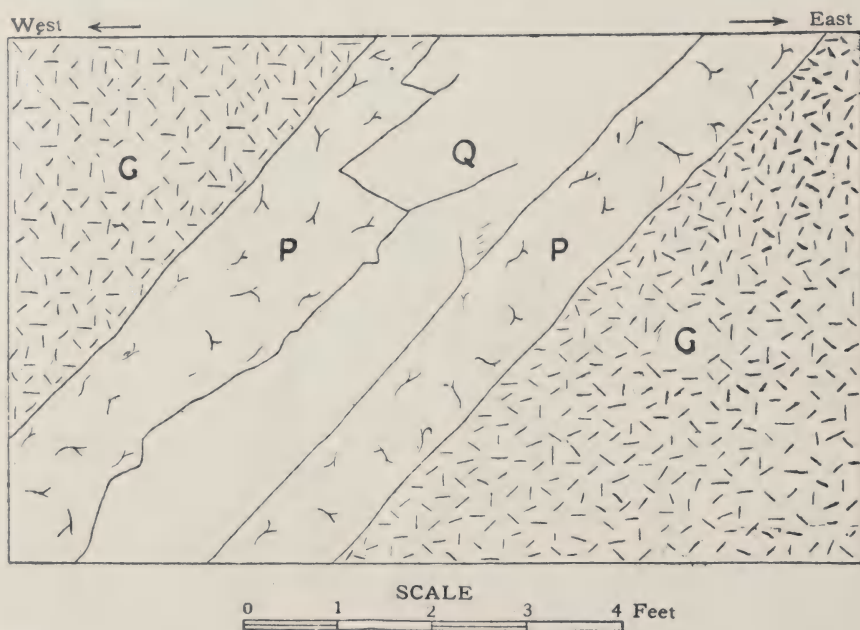


Fig. 3.—Vertical section showing pegmatite dike cutting granite near Rivanna Mills. G, granite; P, fine-grained pegmatite; Q, quartz with a little feldspar and pyrite.

South of Rivanna Mills and also in the road three-quarters of a mile to the east there are numerous exposures of hornblende schist, and in the latter locality they are occasionally cut by small pegmatite dikes.

Carysbrook bridge.—On the east side of Rivanna River, 150 yards below the road leading from Carysbrook to Wilmington, there is an exposure of granite (Spec. 61) containing feldspar phenocrysts ranging up to 1.5 cm. in diameter. The rock contains much less biotite than most of the granites previously described, and is only slightly schistose.

Examined under the microscope, acid plagioclase is seen to be dominant with only minor quantities of orthoclase present. The feldspars show twinning after the albite, Carlsbad, and pericline laws, and in places there are micrographic intergrowths with quartz. The larger individuals frequently show evidence of having been bent and broken prior to the complete solidification of the rock, for the fractures are filled with minerals of later crystallization. The feldspars have been extensively altered to epidote, which is present in irregular rounded grains and in granular aggregates. The quartz contains rutile needles, imperfect zircons, and numerous fluid inclusions some of which show moving bubbles. There is also a small amount of light brown biotite present, but it is largely altered to chlorite. Pyrite is of occasional occurrence in small, cubical crystals, which show more or less alteration to limonite.

A specimen (60) of the granite obtained about 20 yards above the Carysbrook bridge is typical of most of the rock in this vicinity. It is slightly schistose in structure, the feldspars are gray in color, and the biotite is not very plentiful.

In thin section under the microscope it is seen that soda-lime feldspars (probably oligoclase) are dominant over the potash feldspars (orthoclase with a little microcline). The larger feldspars are frequently bent, or ruptured and faulted, and in some cases the fractures are filled with minerals of later crystallization, indicating that there were probably differential movements in the magma after crystallization had commenced and before the rock had completely solidified. The feldspars show twinning according to the albite, Carlsbad, and pericline laws, and they are more or less altered with the production of sericite, kaolin, epidote, and a little calcite. Biotite is present in small light green flakes partly altered to chlorite. The quartz contains numerous fluid inclusions and occasionally moving bubbles. Tourmaline is of sparing occurrence in light brown crystals with ragged outline.

Carysbrook.—A quarry, opened in the granite to obtain rock for use in building the railroad, is located on the south side of Rivanna River, at

the Virginia Air Line railroad bridge, a mile northwest of Carysbrook. This quarry is within 100 yards of the contact between the granite and a chloritic slate which lies on the west.

The rock exposed in the quarry is exceedingly variable in appearance; there are irregular areas or blotches of coarse-grained granite, ranging up to a foot or more in diameter, which are surrounded by a ground-mass of finer material; and the entire rock-mass is cut by irregular fractures running in every conceivable direction. Differential movements have taken place along some of these fractures, resulting in the formation of slicken-sided surfaces and the production of a little light green chlorite.

The masses of coarse-grained granite are composed essentially of feldspar, quartz, and biotite, with a little pyrite in places. Some of the feldspars are 1 cm. in diameter, but the larger ones are frequently fractured and broken. They are white to light gray in color and occasionally show coarse multiple twinning. The biotite flakes, which range up to 0.5 cm. in diameter, have no regular orientation, and the rock shows little evidence of regular schistosity. In places the rock is cut by narrow veinlets, 1 to 2 mm. wide, which are largely composed of feldspar similar to that of the inclosing granite.

The fine-grained facies of the rock contains little or no biotite, consisting chiefly of feldspar and quartz; and as it has a uniform light gray color it is difficult to distinguish between the two minerals. A little calcite occurs in places along some of the fracture lines.

Some of the granite found in the quarry and at other localities in the vicinity contains feldspars that are pink instead of gray in color, but this difference is probably due to alteration with the production of some ferric oxide, as the pink and gray varieties of rock are apparently similar in other respects.

A thin section of the coarse-grained, gray granite was examined under the microscope.^a The feldspars occur in large individuals, ranging up to 5 or 6 mm. in diameter, and are frequently fractured and faulted, while the fissures as well as the interstitial spaces are filled with minerals of later crystallization, chiefly quartz and feldspar. Soda-lime feldspar (oligoclase?) is probably dominant over the potash feldspars (orthoclase with less microcline), but the latter are abundant, and in places may equal the former. The plagioclase shows fine multiple twinning and is much altered by kaolinization, while calcite is also present as a secondary product.

^aThis thin section (Spec. 18) was made from a specimen collected by Dr. J. S. Grasty.

Liquid- and gas-filled cavities occur in some of the fresher feldspars and are abundant in the quartz. Quartz is not as plentiful as in the granites near the James River section. A few of the individual grains show optical distortion and fracturing, but most of them show no pressure effects. Biotite occurs in brownish-green flakes that are of later formation than most of the feldspar, and in places appears to have partly replaced potash feldspar. Chlorite is also present, probably as an alteration product of biotite. Pyrite is one of the minor accessories, occurring frequently in association with biotite—often along the cleavage planes. Ilmenite, partly altered to leucoxene, is present in small grains.

The thin section is crossed by a number of narrow, branching veinlets composed of fine-grained feldspar and quartz, with a little biotite and chlorite. These veinlets cut directly across the larger feldspars and other minerals.

A thin section of the pink granite, which was examined under the microscope, shows no essential difference from the rock described above. The feldspars have undergone greater kaolinization, the biotite is entirely altered to chlorite, and there is a little hornblende present, part if not all of which is secondary. A few ragged crystals of reddish-brown tourmaline, a little magnetite or ilmenite, and scattered grains of titanite are among the minor constituents. The rock is cut by narrow, branching fractures filled with dark green chlorite.

Granite similar to that exposed in the quarry extends southward beyond Carysbrook, and in the railroad cut half a mile south of the station, Ordovician sediments may be seen lying upon the eroded surface of the granite. Most of the rock is badly decomposed, but all fresh specimens seen were nearly massive in texture. The granite in this vicinity is essentially the same as the rock exposed at Carysbrook bridge (see description of Spec. 60, p. 75) excepting that the latter is markedly schistose.

Gold Hill Granite Area.

GENERAL DESCRIPTION.

The Gold Hill granite area lies between Kent's Store and Tabscott, in the northeastern portion of the region mapped. A general description of the area is given under the discussion of the country rock in the vicinity of the Gold Hill vein system (see pp. 176-177), and therefore will not be repeated here.

DETAILED DESCRIPTIONS.

McGloam mine.—The granite (Specs. 161 and 166) exposed on the dumps at the McGloam mine is typical of much of the rock in the Gold Hill area. It is light gray, fine-grained, even-granular, and the minerals distinguishable megascopically are feldspar, quartz, small flakes of dark green chlorite, a little sericite, numerous cubes of pyrite, and occasional grains of magnetite.

Examined under the microscope the rock is seen to vary from granitic to granophyric in texture. The feldspar is probably chiefly acid plagioclase, but twinning can seldom be distinguished. Orthoclase is also present and fine intergrowths of feldspar and quartz are plentiful. A little biotite occurs in the rock, but most of it seems to have been altered to chlorite. Sericite and calcite are fairly abundant as secondary minerals, probably derived from feldspars. The minor accessories include pyrite, magnetite, zircon, leucoxene, apatite, and rutile needles. Fluid inclusions are common in some of the quartz grains.

This rock, which is fairly representative of the granite in the Gold Hill area, differs from the granites previously described in being finer-grained, with a greater development of micrographic intergrowths of quartz and feldspar, and in having no schistosity. It contains less biotite and a relatively larger proportion of some of the minor accessories, such as pyrite and magnetite.

Pieces of hornblende schist are present on the dump of the incline shaft, but the schistosity is not so well developed as in most of the hornblende schists of the district. The rock (Spec. 167) is dark green in color and rather coarsely crystalline, containing bladed crystals of hornblende that range up to 1 cm. in length. The other minerals distinguishable megascopically are white feldspar and quartz, a little chlorite, and numerous small grains of magnetite and pyrite. Under the microscope it is seen that the hornblende is irregular in outline and contains numerous inclusions of quartz and feldspar, and in places there are graphic intergrowths of quartz and hornblende. The feldspar is unstriated plagioclase, probably albite. A little chlorite is present as an alteration product of hornblende, and rutile needles occur in some of the quartz grains.

Another variety of rock (Spec. 165) present on the dump is a chlorite schist containing scattered cubes of pyrite 2 to 5 mm. square, and octahedrons of magnetite ranging up to 2 mm. in diameter. Examined under the microscope, the chlorite is seen to be secondary from hornblende, of which many unaltered fragments remain. Aside from the alteration of

hornblende to chlorite, the rock is essentially the same as the hornblende schist described above.

Big Byrd Creek.—On the road, a quarter of a mile north of Big Byrd Creek and $1\frac{1}{4}$ miles southeast of Kent's Store, there is an outcrop of greenish-gray granite (Spec. 82), which is slightly coarser-grained than most of the rock in the Gold Hill area. Some of the feldspars are 2 or 3 mm. in diameter, and multiple twinning can occasionally be distinguished with the naked eye. Other minerals which may be identified in the hand specimens are quartz, chlorite, magnetite, garnet, and pyrite.

Under the microscope the rock is seen to be composed almost entirely of micrographic intergrowths of feldspar and quartz, the feldspar consisting of orthoclase, acid plagioclase, and microcline in the order named. Feldspar phenocrysts, 3 mm. in length, are scattered through the rock, and in their border portions are intergrown with quartz. Small grains of magnetite and of ilmenite partly altered to leucoxene are present. There is only a little mica—biotite and sericite—in the rock, but chlorite probably derived from biotite is common. Garnets, light pink in color, are of frequent occurrence; they usually contain numerous inclusions of quartz, and in places show micrographic intergrowths. Small zircons are plentiful as inclusions in the larger crystals of quartz.

About 100 yards north of the rock just described there are outcrops of hornblende schist, and the rock with which it is in contact is intermediate in mineral composition between the typical granite of the Gold Hill area and the hornblende schist.

A specimen (83) of this rock is white to light gray in color, fine-grained, and contains small prisms of dark green hornblende in a white ground-mass. There may also be distinguished a few small phenocrysts of feldspar, quartz, a little pyrite, small grains of magnetite, and occasional pink garnets. Under the microscope, the feldspar phenocrysts, ranging up to 2 mm. in length, are seen to be acid plagioclase; they are very irregular in outline, are often broken, and have a corroded appearance. The ground-mass, consisting chiefly of quartz and feldspar, frequently shows micrographic intergrowths. The hornblende shows idiomorphic outlines, is dark-colored, and strongly pleochroic. A little chlorite is present, probably as an alteration product of the hornblende. Ilmenite partly altered to leucoxene and minute inclusions of zircon make up the remaining accessories.

About half a mile south of Big Byrd Creek and $1\frac{1}{2}$ miles southeast of Kent's Store there are outcrops of chlorite schist in the road. The

schist (Specs. 80, 81, and 160) is clearly derived from a hornblende-bearing rock, and under the microscope fragments of unaltered hornblende can be identified. The rock which has undergone the least alteration shows the least schistosity. Small grains of pink rutile are scattered through the rock and can be easily recognized with the naked eye.

Examined microscopically the rock is seen to consist largely of chlorite and needles of secondary hornblende. Unstriated plagioclase feldspar, quartz, and unaltered fragments of primary hornblende are also present, together with numerous small grains of rutile and titanite, and a few inclusions of zircon. The titanite is partly if not entirely secondary after rutile and some of the larger masses contain nuclei of the unaltered mineral.

Hughes farm.—On the Hughes farm, half a mile northwest of the Tellurium mine, numerous pieces of breccia are found on the surface. The rock (Spec. 207) consists of angular and subangular fragments of quartz, feldspar, and fine-grained garnets, which have been more or less silicified and recemented by silica. Small cavities, lined with quartz crystals are occasionally present, and the secondary silica contains a little pyrite. The texture of much of the cementing silica, when it is examined megascopically, suggests that it was originally deposited as calcedony and subsequently altered to quartz. The fragments of country rock are largely replaced by silica.

The distribution of this rock in a northwest and southeast line, a quarter of a mile or more in length, suggests that the breccia was formed by faulting, and that the cementing silica was deposited by solutions circulating along the fracture.

Rosney Granite Area.

There is a considerable area of granite in the vicinity of Rosney, the terminus of the Buckingham Branch of the Chesapeake and Ohio Railway, but because of the lack of outcrops it is not possible to determine its precise extent. On the west it is in contact with quartz-sericite schists and on the east similar schists intervene between the Rosney area and the granite of the Columbia area. It is not improbable, however, that the two areas are connected beneath the sediments of the Farmville Triassic area, which lies a short distance to the southeast.

The granite is fine-grained, very schistose, and varies in color from light to dark gray. A specimen (383) from an outcrop in the road about three-quarters of a mile northwest of Rosney, contains both biotite and hornblende, the two minerals being distinguishable from each other with

difficulty in the hand specimen. In a thin section, which was examined under the microscope, the feldspar was all plagioclase (oligoclase), and no potash feldspar could be identified. Twinning after the albite law is abundant and occasionally a little twinning after the pericline law may be seen. The hornblende is dark green in color and frequently shows idiomorphic boundaries; the biotite varies from brown to green and is strongly pleochroic. Both minerals show alteration to epidote, but no chlorite was identified. Many of the quartz and feldspar individuals are fractured and show optical distortion. Ilmenite, largely altered to leucoxene and limonite, and idiomorphic crystals of zircon make up the minor accessories.

Between the rock just described and the contact, about half a mile northwest, there are no outcrops, but the residual decay indicates the presence of several bands of hornblende schist. In the road half a mile southwest of Rosney a fine-grained hornblende schist is exposed. It is a dark gray, even-granular rock composed for the most part of feldspar, hornblende, quartz, and a little biotite, with occasional small pink garnets.

On the north side of Whispering Creek, 2 miles south of Rosney, several pieces of porphyry were found, which probably belong to a dike, as the country rock in this vicinity is chiefly quartz-sericite schist. The rock is only slightly schistose and is therefore probably of later origin than the granite near Rosney, but it is not improbable that there is some genetic relation between the two occurrences.

The rock (Spec. 388) contains numerous light gray, rounded phenocrysts of feldspar, 5 to 6 mm. in diameter, which are surrounded by a ground-mass of fine-grained hornblende, feldspar, and quartz. Multiple twinning can be distinguished in places with a pocket lens, but most of the feldspars have a rough fracture because of the presence of microscopic inclusions. On weathering the rock gives a deeply pitted surface due to the early decomposition and removal of the feldspar phenocrysts.

Under the microscope the large feldspars are seen to be micropoikilitic in texture, being full of inclusions of quartz and hornblende that range in size up to 0.2 mm. in diameter; they have indefinite boundaries that grade into the surrounding ground-mass; and the extinction angles and index of refraction indicate a composition near labradorite. The hornblende is light green to nearly colorless and contains occasional inclusions of quartz. The quartz grains contain numerous fluid inclusions, and irregular rounded grains of titanite are plentiful, some of them containing nucleal fragments of light yellowish rutile.

About a mile west of Rosney and not far from the contact, there is a large amount of tourmaline present on the surface. Most of it occurs in long black prisms imbedded in vein quartz, but large masses were seen that consisted almost exclusively of small interlaced needles of tourmaline.

Granite at Greeley Mine.

Granite occurs in one of the openings of the Greeley mine, but there are no surface exposures and the occurrence is probably limited in its areal extent. The rock is described in detail on pages 206-207. The appearance of the rock, and the presence of much calcite and coarsely crystalline muscovite, suggests that extensively pneumatolitic action accompanied or followed the intrusion of the granite.

Porphyries.

DISTRIBUTION AND GENERAL DESCRIPTION.

In the district lying between the Gold Hill granite area and the Wilmington embayment of the Columbia area, there are a number of outcrops of feldspar porphyry. Lack of sufficient exposures makes it impossible to determine the size and character of these bodies, but most of them are limited in extent and should probably be classified as dikes. The other rocks occurring in this district are chiefly chlorite schists, hornblende schists, quartz-sericite schists, and quartzites, all of which are intensely metamorphosed.

The porphyries contain phenocrysts of feldspar ranging up to 2 mm. in length, and occasionally small eyes of quartz embedded in a fine-grained ground-mass composed essentially of feldspar, quartz, and usually a little hornblende, which may be more or less altered to chlorite and epidote. They vary considerably in composition, particularly in the amount of ferromagnesian mineral present. The phenocrysts are frequently fractured and the fragments separated, indicating that important differential movements took place during the crystallization of the rock.

The composition of the porphyries, their texture, and their distribution relative to the larger granite areas, are all indicative of their close genetic relationship to the granite and point toward an approximate contemporaneity of origin. Some of them are closely similar to the granite in the Gold Hill area.

DETAILS OF OCCURRENCES.

In the road $1\frac{1}{2}$ miles northeast of Wilmington there is an outcrop of porphyry. It is a light greenish-gray rock (Spec. 63), fine-grained, and

slightly schistose. A few phenocrysts of feldspar, 1 mm. in length, and small flakes of light green chlorite are the only minerals distinguishable megascopically.

Under the microscope the phenocrysts are seen to be well-formed crystals of acid plagioclase, nearly 1 mm. in length, which show twinning after the Carlsbad and albite laws. They are occasionally broken and the fragments separated by minerals of later crystallization. The ground-mass is fine-grained, even-granular, and consists of feldspar, quartz, chlorite, small needles of hornblende, a few flakes of biotite, calcite, epidote, and small inclusions of zircon, titanite, apatite, and rutile.

Another outcrop occurs half a mile farther east where the rock (Spec. 66) is essentially the same. The phenocrysts are slightly larger, ranging up to 1.5 mm. in length, there is a small amount of magnetite present, and alteration has been carried a little farther, so that epidote is more plentiful, occurring in granular aggregates with quartz and a little chlorite.

On the southwest side of Big Byrd Creek, $2\frac{1}{2}$ miles southeast of Wilmington, there is an outcrop of schistose porphyry. The rock (Spec. 68) is light gray with dark blotches due to areas of fine-grained biotite, and contains lenticular eyes of quartz, 4 mm. in length. A few feldspars, crystals of pyrite, red garnets, and a little fine-grained magnetite may also be distinguished in the hand specimen.

Under the microscope phenocrysts of acid plagioclase, over 2 mm. in length, can be identified; and many of them are broken and split apart along cleavage planes, the fractures being filled with the minerals of the ground-mass. The lenticular eyes of clear, granular quartz contain fluid-filled cavities and numerous inclusions of idiomorphic zircon and rutile needles. The ground-mass is fine-grained and consists of feldspar, quartz, flakes of brown biotite partly altered to chlorite, and a little pyrite, magnetite, titanite, and zircon.

In a branch on Mr. Williams' farm, $1\frac{1}{4}$ miles northeast of Rivanna Mills, a rock (Spec. 54) is exposed which is light gray, fine-grained and only slightly schistose. Small pink garnets, pyrite, flakes of light green chlorite, and a little fine magnetite may be recognized with the naked eye. Examined microscopically the feldspar phenocrysts are seen to be smaller than in the rocks previously described, and they are much corroded; the ground-mass is coarser grained, but otherwise the same. The surrounding rock is probably granite, but there are no exposures in the immediate vicinity.

At the road corner, $2\frac{1}{2}$ miles south of Kent's Store, there is an outcrop of fine-grained, bluish-gray rock (Spec. 128) containing small eyes

of quartz 0.5 to 2 mm. in diameter. Under the microscope no feldspar phenocrysts could be identified; the quartz eyes contain rutile needles and well-formed zircons; and the ground-mass is composed essentially of feldspar, quartz, much hornblende in slender green prisms, and a large amount of fine-grained magnetite. A little zircon, titanite, and apatite are present as minor accessories. A similar rock found 50 yards east contains no eyes of quartz.

A rock (Spec. 62), having a ground-mass similar to the one just described, was obtained from a well near the road 3 miles northeast of Stage Junction. Instead of having eyes of quartz there are a few imperfect phenocrysts of feldspar less than 0.5 mm. in length.

A quartz porphyry, differing in texture and mineral composition from the rocks described above, occurs at the Morton mine, half a mile west of Johnson, Buckingham County. A microscopic description is given on pages 197-198.

CAMBRIAN OR POST-CAMBRIAN.

Diorite Dikes.

DISTRIBUTION AND GENERAL CHARACTER.

Dikes of altered diorite occur at several places in the area mapped, but there are a few good exposures, and the rock is of little importance as an areal formation. All occurrences that were observed are practically identical in appearance and mineral composition. The rocks were originally composed essentially of hornblende and plagioclase feldspar, but the latter mineral is now almost completely altered to a fine-grained aggregate of zoisite, epidote, and other secondary products.

AGE.

Since these rocks show little or no evidence of dynamic metamorphism, they must be younger than the pre-Cambrian rocks into which they have been intruded; and the fact that some of them are very slightly schistose indicates that they solidified before the close of the crustal movements which deformed the Ordovician rocks. For these reasons the diorite dikes are believed to be Cambrian or possibly Ordovician in age, but they may be younger.

DETAILS OF OCCURRENCES.

Palmyra.—A dike of partly decomposed diorite outcrops in the road near the northwest corner of the Courthouse yard at Palmyra, but the size of the dike could not be determined. The rock is composed essentially

of partly altered feldspar and dark green hornblende, and shows marked schistosity in the hand specimen. Under the microscope the feldspars are seen to be almost entirely altered to saussuritic aggregates of epidote, zoisite, and other secondary minerals, but in places a few residual fragments of basic plagioclase can be identified. The hornblendes are ragged in outline and show partial alteration to chlorite.

Long Island Creek.—The county road from Palmyra to Wilmington crosses a dike of weathered diorite about 100 yards east of Long Island Creek. The dike appears to be 100 yards or more in width, but could not be traced for any distance because of the lack of exposures. The strike is probably northeast and southwest. The rock is similar in appearance and composition to that described above, excepting that the percentage of hornblende present is slightly greater and the schistosity is scarcely noticeable.

Benton mine.—Pieces of weathered diorite were found on a rock pile in the vicinity of the shaft at the Benton mine. The rock (Spec. 221) is massive, even-granular, and shows no evidence of schistosity. It consists of green hornblende in crystals 1 to 2 mm. in diameter, which are uniformly distributed through a fine-grained, white ground-mass resulting from the alteration of feldspar. Under the microscope the feldspars are seen to be almost completely altered to secondary minerals, chiefly zoisite and epidote. The hornblende shows partial alteration to chlorite, and a little quartz, probably secondary, may also be distinguished.

Bowles mine.—On the Bowles tract, about $1\frac{1}{4}$ miles west of Tabscott, pieces of diorite float were found on the surface, but no outcrops could be discovered in place. The rock is similar in every way to that which occurs at the Benton mine.

TRIASSIC.

Diabase Dikes.

DISTRIBUTION AND GENERAL CHARACTER.

Diabase dikes, or trap rock as they are commonly called, are of occasional occurrence in all portions of the area mapped. They are in no wise different from the other dikes belonging to the same great series, which are found intersecting the older rocks all along the Atlantic slope from Nova Scotia to Alabama. These dikes are especially abundant in some of the Triassic areas, and cut all formations excepting the Cretaceous and later sediments of the Coastal Plain.

In the area covered by the present report the diabase dikes vary in width from a few inches to 200 or 300 feet, and at least one of them can be traced

for a distance of over a mile, its course being marked by occasional outcrops, and the black weather-beaten boulders, which are locally called "nigger-heads." The dikes are usually approximately parallel to the strike of the enclosing rocks, and are nearly vertical.

The diabases are dark brown to black in color, and vary from medium fine-grained to aphanitic in texture. They are composed essentially of lime-soda feldspar, augite, and magnetite, while olivine is present in some and absent in others. These rocks are exceedingly hard and tough, and on account of this fact together with their good cementing qualities, they make excellent material for macadamizing roads.

DETAILS OF OCCURRENCES.

Columbia.—One of the largest and most persistent dikes in the district is exposed in the county road, a mile northeast of Columbia, where it is possibly 100 yards wide. It has a strike of approximately N. 15° E., and can be traced in a southwest direction as far as the river. The large outcrop of diabase half a mile east of Stage Junction lies in the same line of strike and may be a continuation of this dike, but lack of exposures makes it impossible to trace it on the surface.

The rock (Spec. 46) is dark brown, and rather coarse-grained, showing a marked ophitic texture even in the hand specimen. The feldspars range up to 8 mm. in length, and show polysynthetic twinning to the naked eye. Examined under the microscope the rock is seen to be composed of plagioclase, augite, magnetite, pyrite, and occasional flakes of biotite. The augite is mostly colorless in thin sections, but in places is finely twinned with a light green variety. Magnetite and pyrite are both plentiful in small irregular grains. The biotite is dark brown, strongly pleochroic, and shows partial alteration to chlorite. No olivine was identified.

Grannison mine.—A dike of olivine diabase outcrops near the old mill at the Grannison mine, three-quarters of a mile south-southwest of Pryors Crossroads. It has a strike of approximately N. 25° W., but the width and length could not be determined. The rock is coarse-grained and the ophitic texture easily distinguishable to the naked eye. Examined under the microscope (Spec. 97) it is seen to consist of lime-soda feldspars, augite, much olivine, a few grains of magnetite, less pyrite, and a little carbonate (probably calcite). The feldspars occasionally show pericline as well as albite twinning, and zonal extinction is common. The carbonate is probably derived from the alteration of feldspars.

Pemberton.—A mile west of Pemberton, a diabase dike is exposed on either side of the narrow neck of land formed by the sharp bend in the river. Where well exposed the dike is only 5 or 6 feet wide, and while approximately vertical is very irregular in its dip. The strike is nearly north and south. The rock (Spec. 24) is medium-grained, even-granular, and dark gray in color. Under the microscope it shows the typical ophitic texture, and is composed of plagioclase, augite, and small idiomorphic grains of magnetite partly altered to limonite. The rock cut by the dike is a fine-grained, light gray granite-gneiss.

Dillwyn.—A dike of olivine diabase outcrops in the town of Dillwyn (see map, p. 185), and a similar dike, which is described on page 187, is found near the London and Virginia mine, three-quarters of a mile north of Dillwyn. The rock is dark brown in color, medium coarse-grained, and is composed of plagioclase, augite, olivine, and magnetite. The olivine shows extensive alteration to serpentine.

Other localities.—Several dikes of weathered diabase are exposed in the bluffs on the south side of James River near New Canton, and similar dikes were observed cutting the Ordovician slates. Diabase dikes at the Bondurant and McKenna mines are described on pages 195 and 254, respectively. Other occurrences are too numerous to mention in detail, and none of them differs in any material way from those already described.

CHAPTER III. PHYSIOGRAPHY.

INTRODUCTION.

Virginia is naturally divided into three major provinces: (1) the flat-lying Coastal Plain which extends from the continental shelf, now 30 to 50 miles east of the present shore-line, to the fall-line at the head of tidewater; (2) the Piedmont Plateau extending from the Coastal Plain on the east to the foot of the Blue Ridge; and (3) the Appalachian Mountains province which embraces the western or mountain portions of the State. (See fig. 1.)

The Piedmont Plateau lying between the Coastal Plain and the Appalachian Mountains has a width of about 40 miles in the northern portion along Potomac River, but going south it widens until at the Virginia-Carolina state-line it extends for nearly 175 miles. The district under consideration is located in the center of the Piedmont Plateau province where the width is about 75 miles. The district presents the general surface features characteristic of the Piedmont Plateau throughout Virginia; low relief, a network of streams which afford perfect drainage to the region but which are heavily loaded with sediment, and a deep mantle of residual decay which covers most of the country except where the larger streams have cut down their valleys into the underlying rock.

RELIEF.

The elevations indicated on the map of the area (see Pl. I, in pocket at back of book), by means of contour lines, are approximately correct, and serve to portray the principal physiographic features. The topography, as shown on this map, is adopted from the topographic sheets of the United States Geological Survey, with corrections by the writer.

The most characteristic feature of the relief is the absence, over the entire area, of any notable elevations, with the single exception of Willis Mountain. This fact is forcibly impressed on the observer by the bird's-eye view of the country obtained from the top of Willis Mountain. Looking from this elevation, the country appears as a broad, flat plain, stretching from the foot of the mountain toward the north, east, and south as far as the eye can reach, while toward the west it is limited only by the foothills of the Blue Ridge.

In traveling any great distance across country, one soon finds that the surface instead of being perfectly level, is gently rolling, and consists, for the most part, of broad, flat-topped ridges and comparatively narrow valleys. If, however, one follows one of the main ridge roads, which have from the earliest days been the chief transportation routes of the country, the illusion of a vast level plain is maintained, for many of the ridges extend along distances with little variation in altitude. Thus, in traveling over the roads that lead from Cartersville to Cumberland, New Canton to Dillwyn and Buckingham, or from Stage Junction north by way of Wilmington, one may go for distances of 15 or 20 miles over an apparently level country.

Glancing at the map, it is seen that neighboring ridges have approximately the same elevations, but that in passing across the area from east to west the height of the elevations gradually increases; along the eastern border of the area the ridges are about 450 feet above sea level, while in the western portion they average from 550 to 600 feet in elevation. If it were possible to fill in all of the valleys level with the tops of the ridges, we would have a broad, flat plain sloping gently toward the ocean, and it is believed that this was the condition of the land surface at a former period, before the streams had cut their channels down to their present levels.

The rivers and larger creeks have cut their valleys deepest, about 250 feet below the present surface of the old peneplain, the smaller creeks somewhat less deeply, and their tributary branches only from 50 to 150 feet. All of the larger streams flow through narrow trench-like valleys with very limited bottom lands. In places where the rocks are especially resistant, as is the case with the quartzite beds at Bremono Bluff, the river lowlands are practically absent and the stream is bordered by almost vertical cliffs. (See Pl. III, and fig. 2.)

Willis Mountain, in the southwestern corner of the area, projects abruptly from the average level of the Piedmont Plateau and rises to a height of 1,159 feet above sea level. It is a prominent feature of the landscape for miles around, and is the most noticeable elevation found in the State, east of the outlying ranges of the Blue Ridge. (See figs. 4 and 5.) Topographically, it is a narrow ridge extending about two miles in a north and south direction, and the crest of the ridge is formed by a narrow wall of rocks, perhaps 100 feet high, which is so nearly vertical that it can be scaled only in places and with difficulty. (See Pl. IV, fig. 1, and Pl. VI, fig. 2.) The dip of the strata is slightly toward the west, and the

large fragments which have fallen along the eastern base have rendered this the easiest direction of ascent. From the foot of this wall-like precipice the mountain slopes steeply down to its base. The rocky ridge



Fig. 4.—North end of Willis Mountain from the west.



Fig. 5.—South end of Willis Mountain from the west.

forming the crest of the mountain is notched in several places, so that a number of distinct summits occur. The deepest of these notches is near the south end of the mountain, and the southern knob which it separates from the main ridge is locally known as Round Mountain. Willis

Mountain owes its origin to the resistant nature of the cyanite schist which outcrops along its crest, and which has offered greater resistance to erosion than any other rock in the region.

DRAINAGE.

The great master-stream of the area, James River, flows in a general southeasterly direction and cuts directly across the strike of the upturned edges of the rock strata, maintaining its course without reference to variations in their hardness. With its headwaters rising among the ridges of the Alleghany Mountains, James River flows eastward, cutting its way through the Blue Ridge as well as all minor barriers that rise athwart its course, and finally empties into the Atlantic Ocean. This independence of the chief structural features of the country, together with its intrenched meandering curves, proves that the river developed its course on a broad, level plain, before the present ridges were formed. Such a river is called an antecedent stream.

The principal streams draining the area and entering James River from the north are Rivanna River and Byrd Creek (see map, Pl. I). Both of these flow southeasterly across the strike of the upturned rock strata and show deeply trenched winding valleys, indicating that they are also antecedent streams.

Slate and Willis rivers are the largest streams that cross the area and enter the James from the south. It should be noticed that both rivers, after flowing in a general northeasterly direction throughout most of their length, suddenly change their courses as they approach the James, and enter it from an easterly or even a northeasterly direction; and, moreover, their lower courses are extremely crooked, while their upper valleys are fairly straight. These two rivers were doubtless at one time superimposed streams similar to those on the other side of James River, but as their direction of flow was nearly parallel to the strike of the rock strata, their courses were more easily modified and adjusted to the rock structure. This possibly explains the peculiarities in the courses of these streams and also the fact that their valleys are slightly broader and less steep than those of the corresponding streams on the opposite side of James River. Slate and Willis rivers may be considered as antecedent streams that have subsequently undergone modification and are now in partial adjustment to the structure.

Appomattox River, which crosses the southeast corner of the area, is clearly another antecedent stream similar to James River into which it flows some distance beyond the borders of the map.

It is thus seen that all the larger streams of the area are either antecedent streams or streams that are only in partial adjustment to the structure, and that they all show a strong tendency to flow in a southeasterly or easterly direction.

Most of the creeks and many of their branches are streams that owe their location to the underlying rock formations. These streams flow northeasterly or southwesterly parallel to the structure of the country, their direction of flow being controlled by their proximity to some larger antecedent stream. Hunt Creek, Phelps Creek, and Little Byrd Creek may be mentioned as good examples of structural control of drainage.

Hunt Creek has eroded its valley in the long, narrow area formed by the Arvonja slate belt, while the ridges on either side are composed of more resistant rocks—schistose quartzites and conglomerates.

Phelps Creek runs in a northeasterly direction through an area of highly metamorphosed schists and enters James River just east of New Canton. The ridge on the west side of the valley is composed of quartzite, while on the east stretches the granite area. A complementary creek flows southwest and enters James River directly opposite.

Little Byrd Creek flows southwest within the area of pegmatite, which is less resistant than the granite and hornblende schists on either side.

The hundreds of small tributary branches that drain into the larger streams flow in every conceivable direction, their courses being controlled partly by the geological structure, but chiefly by their proximity to one of the larger streams.

Most of the streams draining this area are rather swift and flow over occasional rapids, due to outcropping ledges of harder rock; their waters are usually muddy because of the large amount of fine material carried in suspension which has been derived from the residual soils that almost everywhere cover the underlying rocks.

It is interesting to note that in the case of some of the larger streams that are in structural adjustment, such as Little Byrd Creek on the north side of James River and Muddy Creek on the south, the principal tributary branches all enter from the west. This phenomenon is due to the eastern slope of the peneplain in which the streams have eroded their valleys.

The movement resulting in the tilting of this plain did not take place all at once, but undoubtedly extended over a long period of time, and was probably interrupted by periods of quiescence. Every increase in the eastern tilt of the land surface resulted in an increased velocity of the streams flowing in an easterly direction with a corresponding increase in

their powers of erosion. Streams flowing westward had their velocities diminished and if the amount of movement was sufficient the direction of flow may even have been reversed in some cases. The net result of this tilting was to cause the streams flowing in an easterly course to cut backward and lengthen their valleys faster than the streams flowing in the opposite direction. This process may have been accompanied by an easterly migration of the parent stream since the tilting would tend to induce greater erosion along the eastern bank. The bluffs appear to be somewhat more prominent on the east sides of these streams than on the west, but the difference is certainly not great. The chief result of any easterly displacement of the parent stream would be to lengthen the courses of its tributaries from the west and shorten those from the east, but it is not believed that this was an important factor in producing the unsymmetrical streams described above.

The rapid headward erosion of easterly flowing streams, caused by the tilting of the peneplain would bring about a condition favorable to stream capture; that is to say, the stream with greater velocity might cut its way back to some neighboring stream and divert the upper portion of its drainage. A close study of the region lying west of Little Byrd Creek indicates that this may have taken place, and that the headwaters of some of the branches north of Lantana, which now flow east into Little Byrd Creek, at one time drained southward into the large branch which enters Little Byrd Creek a mile above its mouth.

The principal facts in favor of this theory are as follows:

(1) The large branch which heads just east of Lantana and flows south into Little Byrd Creek has a valley that is almost as broad as that of Little Byrd Creek itself.

(2) The divide near the headwaters of this branch is low and in places swampy.

(3) Several of the tributary branches draining the area northeast of Lantana have a sharp bend in their courses which is approximately in alignment with the prolongation of the valley running south from Lantana.

(4) On some of the low ridges northeast of Lantana residual patches of placer gravel were formerly worked for gold. The position of this gravel is high above any of the neighboring streams, and these remnants are all that is left to indicate the location of an old stream bed which has long since been almost entirely removed by erosion.

PHYSIOGRAPHIC HISTORY.

It is known that this region passed through a long and varied history before the present physiographic features began to take form; it underwent

many changes in elevation, and for long periods of time it was depressed below sea level while the great series of sedimentary beds was being deposited. Later these beds were consolidated into hard rock and subjected to compressive forces which produced the complicated system of folding and faulting that is so noticeable wherever the rocks are well exposed. This process was accompanied and followed by intrusions of igneous rocks, and the area was elevated high above sea level.

As soon as the land appeared above water, the agents of the atmosphere began their work of decomposition and disintegration, and the newly formed streams began to wear away the land surface and transport the products of weathering to the ocean, where the material was redeposited to form new beds of sediments. Denudation was continued until the region was beveled across hard and soft formations alike, and the country reduced to a condition bordering on base-level. Such a surface is known as a peneplain.

The area has undoubtedly experienced several periods of peneplanation followed by renewed elevation of the land surface, but it is unlikely that the Piedmont section as a whole has been depressed below sea level since Ordovician time.

Following a period of base-leveling, the surface was warped enough to allow the Newark beds to be laid down in long, narrow trough-like basins, but, since that time, degradation has continued without interruption. The earliest great peneplain of which evidence remains extended far beyond the limits of this small area, and has been called the Kittatinny peneplain.^a It probably dates from the Cretaceous period.

In many places in the Appalachian States peneplains of later date than the Kittatinny plain have been noted, and while it is possible that periods of subsequent base-leveling may have occurred in this section, they have not been identified, and it is improbable that more than one plain can be distinguished within the limits of this area.

It is impossible to accurately determine the thickness of the material removed during the ages in which this degradation of the land surface was going on, but certainly it is to be measured in thousands of feet. All of the changes outlined above took place gradually and covered a long period of time. While we can not even approximately estimate the length of this time as measured in years, it must have been very great even in comparison with the time which has since elapsed.

^aWillis, Bailey, *The Northern Appalachians, Physiography of the United States*, p. 189.

During the latter stages of peneplanation decomposition proceeded much faster than degradation; the products of rock decay accumulated more rapidly than they could be removed by the slow-moving streams, which had almost attained base-level, and a deep mantle of residual soil was gradually formed that completely covered the hard rocks below.

The appearance of the surface at that time was probably not very different from that of the lower Mississippi valley to-day. The land was flat and featureless and elevated but little above sea level. Willis Mountain was probably the only elevation within the limits of this area that stood above the monotonous level of the plain. The stubborn resistance to weathering offered by the rocks forming this mountain served to protect it from the complete reduction that had befallen the surrounding area, and left it standing as a solitary monadnock. The rivers meandered sluggishly over the land in wide curves, and there were no marked divides. The course of these streams is not known, but many conditions indicate that they possibly drained toward the west.

In this condition a very slight tilting of the land surface was sufficient to change the courses of the streams, or even cause them to flow in the opposite direction, and it was upon this surface that the new system of drainage represented by the present antecedent streams was inaugurated.

The new streams, assuming their positions while the rocks of varying hardness were still covered by a deep blanket of residual decay and alluvium, were not influenced by the structure of the underlying formations, and therefore ran slowly in winding curves closely coincident with those that they now possess. The establishment of the new drainage, however, was shortly followed by a progressive elevation of the land which quickened the streams, and they began the work of deepening their channels.

After cutting through the soft overlying material and exposing the fresh rock below, the larger streams continued the work of corradng their channels in the more resistant formations. As fast as renewed elevation of the land surface raised the hard beds athwart their course, the streams, confined to their channels and restrained from altering their courses by the deep valleys which they had excavated in the softer material, were forced to cut through hard and soft strata alike. It was in this way that the larger streams were superimposed upon the structure of the undecomposed underlying rocks.

The fact that the rivers have not been able to cut their channels in hard rocks as rapidly as in the softer formations, accounts for the rapids

that frequently occur. The rapids in James River at Bremono Bluff furnish a good example. Here the river flows across beds of hard quartzite which, dipping vertically, are interbedded with softer mica-garnet schists. Because of the greater resistance of the quartzite to erosive action, the river has not been able to cut its bed downward or to widen its channel in it as rapidly as in the softer rocks, and therefore the quartzite beds stand out as ledges from the bottom of the river and project from the sides of the valley in bold cliffs. (See fig. 2, and Pl. III.) At the bridge the valley is only 500 yards wide from bluff to bluff and there are practically no bottom lands, but at a distance of only one mile up or down the river, the valley is a mile or more in width, the river being bordered by broad, alluvial flats which at times of very high water may be completely flooded.

While the larger streams were able to deepen their valleys, even in the hardest rock, and continued to flow across the strike of the strata, the secondary streams were not strong enough to maintain their courses in opposition to the forces tending to divert them into conformity with the structure. As a result, these streams were gradually diverted to the areas of softer rock, and this adjustment was more readily brought about as the original direction of flow was more nearly parallel to the rock structure.

It was through this struggle between the eroding power of the streams and the slowly rising land surface that the existing surface configuration was developed.

At present the larger rivers of this area are, in some places, cutting their channels deeper, while at others, as evidenced by the large islands and wide areas of bottom lands, they have begun to deposit part of their burden. The valleys are slowly being widened, chiefly through the decomposition and disintegration of the rocks under atmospheric agencies.

The smaller streams have not yet cut down through the decomposed material to fresh rock, but the rate at which they are now cutting is probably in most cases greater than that of decomposition.

Evidence of the former position of the rivers is furnished by deposits of water-worn gravel, representing the remains of old river terraces, that are found at various places high above the present level of the river. One of these old river terraces, some 200 feet above the present river bed, is located near Stearnes on the north side of James River, where it can be traced up stream for a distance of about a mile.

A profile of James River shows a rather sharp change in the grade, where the river crosses from the sedimentary rocks to the granite, just

below Brems Bluff.^a From Lynchburg to this point, a distance of 80 miles, the river falls an average of 3.71 feet per mile, while flowing over the granite from this point to Lorraine, 12 miles above Richmond, which is a distance of 91 miles, the river falls only .606 feet per mile. In both cases the grade is fairly uniform. The change is too sharp to be accounted for by the natural increase in the grade of the stream with its distance from the mouth, and is probably due to the difference in the character of the formations. Another possible explanation is that the tilting of the peneplain has not been uniform, but this would hardly account for the localization of the change in grade at this particular point. There is no evidence of faulting, and the rock exposures along the bluffs are particularly good in this vicinity, so that it would probably show if present.

^aSee Plate VI, opposite p. 94, Hydrography of Virginia, Bull. No. III, Geol. Survey of Virginia, 1906.

CHAPTER IV.

STRUCTURE AND METAMORPHISM.

INTRODUCTION.

Previous descriptions have brought out the fact that the dominant rock formations occur in zones or belts extending in a northeast and southwest direction, and dipping at high angles, usually toward the east. Sedimentary rocks, from the manner of their formation, are necessarily laid down in nearly horizontal beds; but, in the region under consideration, the older rocks have been subjected to severe compressive stresses which have crumpled and squeezed the beds into close folds, mashing even the hardest rocks into schists and gneisses. The rocks have also been profoundly altered by the intrusion of large igneous masses. Subsequently erosion has gradually removed the overlying material, beveled off the edges of the upturned beds, and in places exposed the underlying igneous intrusives.

The lack of accurate knowledge concerning the structural relations of the rocks in the surrounding territory, and the scarcity of exposures, due to the great depth of residual rock decay, make it impossible to work out many of the details of structure in the limited area considered in this report, but some of the more important features will be discussed below.

STRUCTURAL FEATURES.

Folding.

There are three well-defined belts of pre-Cambrian metamorphic rocks of sedimentary origin, which consist essentially of knotted schists and interbedded quartzites. The most easterly of these belts extends southwest from Shannon Hill to Stage Junction; the middle belt is exposed in the river bluffs near New Canton and extends in a northeast and southwest direction approximately parallel to the first; the third belt is located along the northwestern margin of the map (Pl. I) between Palmyra and Strathmore. This areal distribution of the rocks is strongly suggestive of folding, and there are a number of facts which indicate that there is an anticlinal fold between the eastern and middle belts, and a synclinal fold between the middle and western belts.

In the eastern belt the rocks dip southeast at an average angle of 45° , in the central belt they stand nearly vertical, and in the western belt they

dip at an angle of 75° to 80° southeast. The central and western belts are separated by the long narrow area of Ordovician sediments, which were deposited unconformably upon the eroded surface of the older pre-Cambrian rocks; the eastern belt is almost entirely cut off from the other rocks by the large areas of intrusive granite (see p. 102).

The crustal movements continued with less intensity after the deposition of the Ordovician sediments, and these beds were compressed into the synclinal fold to which they owe their preservation. The Ordovician slates are extensively faulted and crumpled into innumerable minor folds, but the synclinal nature of the belt is shown by the presence of a basal conglomerate along the contact with the older rocks on both sides. The close folding and faulting shown in the section along the south side of James River (see Pl. VII) indicates that the beds were probably of no great thickness, and that they could not have been folded under conditions of very deep burial. The lack of a well-developed slaty cleavage in slate from the bottom of the synclinal trough has been commented on in a previous chapter (see pp. 45-46).

In the time that has elapsed since their deposition and subsequent folding, erosion has removed all of the Ordovician sediments except the long narrow belt of rocks, preserved in the bottom of the synclinal trough. Rivanna River has cut completely through this narrow remnant and exposed the underlying granite, thus proving the shallow character of the formation. In the railroad cut, half a mile south of Carysbrook, the Ordovician sediments are exposed resting on the eroded surface of granite (see Pl. VI, fig. 1), and as the river is approached the beds gradually thin out until they completely disappear. The slates are again exposed along the upper portion of Long Island Creek between Palmyra and Wilmington; and the creek, which in both its upper and lower portions is in direct alignment with the strike of the rocks in the two areas, probably owes its position to the slate belt, now partly removed by erosion.

The small detached slate area, paralleling the main belt a short distance north of Fork Union station, probably represents a minor fold which has been separated from the main belt by erosion; and minor folding offers the most plausible explanation for the widening of the slate belt in the section along the south side of James River.

It is not unlikely that there are numerous subordinate folds superimposed on the major folds of the pre-Cambrian rocks, but the nearly isoclinal dip, together with the lack of exposures, makes it impossible to work out minor details of this character. The presence of these minor folds is occasionally indicated by discordance between the bedding and schistosity—shown in Spec. 342 from the Buckingham mine.

Faulting.

Small faults, usually of the thrust type, are plentiful in the Ordovician slates and may be seen at many points in the bluffs along James River; they have also been detected in the pre-Cambrian rocks, and it is probable that many are concealed by the steep monoclinal dip of the bedding and schistosity. All the faults observed are approximately parallel to the strike of the rocks and it is unlikely that many of them cut across the structure. No large faults were definitely located along the boundaries between different formations although it is not improbable that such faults exist in a few places.

Some faulting has taken place in this region as recently as Triassic times, for a number of faults have been discovered in the Farmville area (see p. 47), as well as in the other Triassic areas of Virginia. The displacement along these recent faults, however, is comparatively small and they do not seem to have affected the structure of the country in any important way. The occurrence, during the past few years, of several feeble earthquake shocks in the vicinity of Arvonnia is possibly due to adjustments that are taking place along some of these fractures.

The determination of faults in the granites and related igneous rocks is a more difficult problem, but the presence of cemented breccia on the Hughes farm, $2\frac{1}{2}$ miles west of Tabscott, and on the Dickey farm, 2 miles southeast of Cremona, indicates that fracturing with more or less faulting has taken place at these points.

Jointing.

Joints are very plentiful in all portions of the area mapped, and, while they run in every conceivable direction, they show a decided preference for certain quarters of the compass. Joints having a general northeast-southwest strike, approximately parallel to the schistosity, are most common and those with a northwest-southeast trend are second in importance. North-south and east-west strikes are comparatively rare.

As a general rule joints are more closely spaced in the rocks of sedimentary origin than in the more nearly massive and compact rocks of igneous origin. For example, in the railroad cut half a mile south of Carysbrook, where Ordovician sedimentaries are exposed resting on the eroded surface of the older granite, the principal directions of jointing are N. 25° E., N. 60° W., and parallel to the contact which dips southeast at an angle of less than 30° . In the granite the joints are spaced 2 to 4 feet, while in the slate they are only 2 to 8 inches apart.

Schistosity.

Schistosity is that property of rocks which causes them to break most readily along certain parallel planes, and is due to mashing accompanied by more or less recrystallization of the mineral constituents. It is usually induced by the same compressive forces which result in folding and faulting, and is therefore parallel to the axes of the major folds.

With certain exceptions, noted later, the strike of schistosity throughout the region mapped, is northeast-southwest at slightly varying angles, and the dip is usually steeply inclined toward the southeast. In the pre-Cambrian rocks of sedimentary origin the schistosity is almost always parallel to the strike and dip of the bedding; and the few exceptions to this rule which were noted are probably due to the presence of subordinate folds superimposed on the major folds. There are greater variations in the relation of schistosity to bedding in the Ordovician slates than in the older rocks, for these have not been subjected to such severe compression and the dip of the bedding is therefore less uniform.

On the Stage Junction road, a mile north of Columbia, there are a number of rock exposures in the vicinity of the contact between the intrusive granite and the older pre-Cambrian schists and quartzites. In these exposures the strike of the schistosity is approximately parallel to the contact, varying from N. 15° to 24° W., and dipping southwest at an angle of about 45° . This exception to the general trend of the schistosity affects both the sedimentary and the igneous rocks and is probably due to the intrusion of the latter.

In most places the boundary of the granite area runs in a general northeast-southwest direction, approximately parallel to the strike of the bedding and schistosity of the neighboring sedimentary rocks; and in the few places where the contact cuts across the strike of the latter, the exposures are not sufficient to determine whether the anomaly described above holds true in other localities or not.

A peculiar form of schistosity was observed in slate from the bottom of a synclinal fold (see pp. 45-46). Instead of the usual slaty cleavage it has a prismatic cleavage, which causes the rock to break with equal readiness in all directions parallel to the axis of folding, while it breaks with much greater difficulty at right angles to this axis.

The schistose structure possessed by most of the granites and related igneous rocks of the district, was probably induced by pressure or mashing of the massive rock, but the gneissoid banding shown in certain localities (see Pl. VIII, fig. 1) is evidently a primary flow structure. In

the Elk Hill complex (see p. 57) granite occurs in the form of innumerable dikes, varying from a few inches to 50 feet or more in width, which have been intruded into the hornblende schist; and while for the most part the granite follows the planes of schistosity in the older rock it occasionally cuts directly across. Some of the granite dikes have a much contorted gneissic banding; and since the contortions are not shared by the older schist, they can not be explained by pressure, and must be due to movements in the partly solidified granite.

Structural Relations of the Granite.

Granite is a rock which forms only under conditions of deep burial, and therefore a large amount of overlying material must have been removed by erosion in order to expose the present surface. There is nothing to indicate that the material removed was essentially different from the formations that remain in contact with the granite, and that certainly in places overlie it. From this it should not be inferred that these same sedimentary formations necessarily extended for an indefinite distance toward the east; but it is believed that they formerly covered the granite in the immediate vicinity of the contacts, and that they once covered the large areas, such as the one lying between Stage Junction and Fork Union, which are still partly or wholly surrounded.

The areal distribution of the two formations indicates that the contact between the granite and the pre-Cambrian sedimentaries is not a uniform plane, but that the granite rises higher along certain lines that probably represent anticlinal folds. Such a line connects the granite embayment heading near Wilmington with the area lying between Kent's Store and Tabscott, and there is evidence that the intervening region is underlaid with granite at no great depth. The sedimentary rocks in the region between these two granite areas are intensely metamorphosed, hornblende schists are common, and there are numerous intrusive bodies of porphyry and pegmatite. The latter, which are probably differentiated from the underlying granite, are limited to this particular region and do not occur in the schists on either side. Some of the facts indicating the presence of an anticlinal fold in this vicinity were given in a previous paragraph, and it is interesting to note that the gold veins are located chiefly in the limbs of these folds not far from the granite contact.

In the southern portion of the area mapped the exposure of granite at the Greeley mine, a mile southwest of Gravel Hill, is in direct line of strike with the Rosney granite area; and the sedimentary rocks lying

between these two localities show evidence of contact metamorphism. Some of the rocks, as at Tower Hill, are largely altered to garnet and sillimanite, and tourmaline-bearing quartz veins are plentiful. It is believed that granite closely approaches the surface along this northeast-southwest line, and that the few exposures which occur are located where erosion has removed the overlying cover of sedimentary rocks. It is probable that much of the pre-Cambrian sedimentary area is underlaid with granite at greater depths.

Relations of the Hornblende Schists to the Granites.

Hornblende schists are plentiful in the Columbia granite area and in the Elk Hill complex, but are rarely found elsewhere in the area of granitic rocks; their distribution and occurrence have been described in detail in a previous chapter. There are two hypotheses that may be offered in explanation of the presence of these schists: (1) They are due to the partial solution and recrystallization of inclusions of the country rock, and (2) they represent segregations from the original granite magma. No chemical analyses are available, but all of the field and petrographic evidence is in favor of the latter hypothesis.

One of the chief objections to the first hypothesis is that, while the schists are more plentiful near the boundary of the granite area, there is no noticeable variation in their abundance or in their mineral composition consequent upon changes in the character of the sedimentary rocks along the contact. Moreover, they are abundant in the Elk Hill complex, which is situated far from the contact with sedimentary rocks. Another serious objection is the fact that the central portions of even the largest hornblende areas show no evidence of a sedimentary origin.

On the other hand, the areas of hornblende schists vary in abundance and size with the mineral composition of the granite; they are most plentiful in the southern portion of the Columbia area where ferromagnesian minerals, especially hornblende, are abundant in the granite, and they are absent in the embayment between Wilmington and Carysbrook, where the ferromagnesian minerals are at a minimum. The reasons for believing that the granite near Carysbrook solidified later than the rock in other portions of the area were given on pages 62-63, and the field evidence is conclusive in showing that the hornblende schists crystallized prior to the complete solidification of the associated granite.

The hornblende schists are remarkably uniform in mineral composition, and the variations from the normal are all intermediate between the

granite and the typical schist. Occurrences showing a gradation of granite into hornblende schist were described in detail in a previous chapter (see pp. 66-68). On approaching a large area of hornblende schist the potash feldspars and muscovite disappear from the granite and finally hornblende gradually takes the place of biotite.

It seems probable that the hornblende schist and granite of the Elk Hill complex belong to the same period of intrusion as the rocks of the Columbia area, for they are similar in appearance and mineral composition. Another fact, which lends support to this supposition, is the absence of hornblende schists along the contact between the Columbia area and the pegmatite belt, although the schists commonly constitute a border facies of the granite. This suggests that the Elk Hill complex may represent the real eastern border of the Columbia granite and that the intervening pegmatites may be residual differentiates from a common magma.

As yet little is known of the processes by which rock magmas are differentiated into rocks differing widely in mineral and chemical composition. In the absence of numerous chemical analyses of the rocks it is impossible to discuss the various theories of rock differentiation and their application to the present problem; but some of the more important facts concerning the differentiation of the hornblende schists will be summarized, and the probable processes will be briefly outlined.

The hornblende schists crystallized prior to the granites with which they are associated, and they are more plentiful where the granite is hornblende-bearing. In the Columbia area the hornblendic granites probably solidified prior to the granites containing little or no hornblende. Where hornblende occurs in the granites it is one of the minerals of early crystallization. The bodies of schist vary in size from small schlieren up to areas that are over a square mile in extent, and they are most abundant in the marginal portions of the granite area.

The hypothesis outlined below, while only tentative in its nature, is based on the facts given in the previous descriptions, and serves to explain the observed relations between the hornblende schists and the associated granite. As the original magma gradually cooled, crystallization began in the border portions where the temperature was lowest, the more basic minerals separated out first; and in this way the marginal areas of hornblende rock were formed. Differential movements, occurring after the basic border facies of the magma had partly or wholly crystallized, resulted locally in the intrusion of the still-fluid portions of the magma into the

solidified rock, and caused the interleaving of the two rock types that is such a prominent feature of the Elk Hill complex. The detached areas of hornblende schist found within the central portion of the granite may represent material derived from the border portions, or possibly they are due to segregations *in situ*.

The differential movements mentioned above may have brought portions of the solidified rock into contact with magma having a higher temperature and resulted in some resolution. This possibly explains the occurrence of intermediate rock types with unusual coarse textures, for when recrystallization followed upon partial solution any undissolved crystals would prevent supersaturation, which is commonly the cause of rapid crystallization and fine texture.

It is believed that the granite near Carysbrook, which is low in ferromagnesian minerals and contains no marginal areas of hornblende schist, was intruded in a partly crystallized condition (see pp. 62-63), and was the final portion of the magma to solidify.

METAMORPHIC FEATURES.

Regional Metamorphism.

All the older rocks in the area studied, both those that are sedimentary and those that are igneous in origin, have been deeply buried in the anamorphic zone, and most of them show pronounced effects of dynamic metamorphism. Megascopically these effects are manifested chiefly by the development of a schistose structure, which in some instances is accompanied by gneissoid banding. In a rough way the degree of alteration is proportional to the age of the rocks; the pre-Cambrian sediments are the most schistose, the Ordovician rocks show less effects, and the Triassic rocks are practically unaltered. The degree of schistosity is also dependent on the composition and original texture of the rock. The pre-Cambrian quartzites, for example, are almost massive, while the fine-grained schists with which they are interbedded have a highly developed cleavage and almost perfect parallel orientation of the mineral constituents.

Microscopically, the chief evidence of dynamic metamorphism is furnished by the fracturing, granulation, and optical distortion of certain minerals, by recrystallization, and by the complete or partial alteration of primary to secondary minerals, such as sericite and chlorite.

The development of the pseudophenocrysts that occur in the knotted schists took place under mass-static conditions, for these minerals are of later formation and show no regular orientation relative to the schistosity of the rock.

Since the metamorphism of the different rock types has already been considered in the chapter on descriptive geology and petrography, a detailed discussion will not be given here. While the alterations outlined above have been attributed chiefly to mass-mechanical action under conditions of deep burial, it is probable that the changes have been greatly aided by the intrusion of the vast masses of igneous rock, only part of which have been exposed by erosion.

Contact Metamorphism.

INTRODUCTION.

Under contact metamorphism, those changes will be discussed which are set in action by intrusive masses of molten rock. The metamorphism of the wall rock is manifested by recrystallization, usually with the production of new and characteristic minerals, and by changes in texture; the effects are at a maximum near the intrusive and decrease in intensity with the distance from the contact. The intrusive likewise shows more or less variation in texture and mineral composition as the contact is approached.

It is now generally believed that the changes which take place in the vicinity of igneous intrusives are due chiefly to the action of highly heated water and other mineralizers set free by the solidifying magma. These highly heated vapors or gases, probably carrying a certain amount of silicates and other substances in solution, penetrate the surrounding rock through minute fractures and pores, bring about the formation of new minerals, and deposit their dissolved material. Acid magmas, such as those from which granites crystallize, are supposed to be richly provided with these mineralizers, and therefore commonly produce greater effects than more basic magmas.

All the older rocks in the James River basin have been subjected to intense dynamic metamorphism and it is often difficult to distinguish between alterations due to this cause and those due solely to igneous intrusives. The diabase dikes, and other small masses of intrusive igneous rock, have produced practically no effect on the sedimentary rocks along their contacts, but in the vicinity of the granite area the older rocks have been intensely altered by contact action. Because of the lack of good exposures, there are only a few places where the contact between the granite and the sedimentary rocks can be observed and studied; the best of these is furnished by the bluffs along James River and Phelps Creek in the vicinity of New Canton. The rocks in this locality will now be described in detail.

DETAILED DESCRIPTIONS OF CONTACT PHENOMENA.

JAMES RIVER SECTION ACROSS GRANITE CONTACT.

On the south side of James River near New Canton, the contact between the granite and the pre-Cambrian sediments is marked by a belt of hornblende schists, 700 to 900 yards wide, part of which are sedimentary in origin, while part represent a basic border facies of the granite. In the absence of chemical analyses it is impossible in many cases to distinguish between the rocks that are igneous and those that are sedimentary in origin, and indeed they are to a certain extent interleaved with one another; therefore the line drawn on the map (Fig. 2) to show the contact between the two formations is only approximate. On the east side, the hornblende schists pass into granite, while on the west they grade into the knotted schists which are interbedded with quartzites.

The quartzites are described in detail on pages 16-18, and the knotted schists on pages 30-34. At a distance from the contact the knots or eyes present in the schist consist of impure siderite; about 900 yards east of the hornblende schists, biotite begins to take the place of siderite in the eyes, and within 600 yards of the hornblende schists garnets appear. The change is one of gradual increasing intensity of metamorphism as the contact is approached; but there is one exception to this rule—the knotted schists occurring along the east side of the quartzite, about 700 yards from the hornblende schists, are intensely altered in the immediate vicinity of their contact with the quartzite, probably because the latter rock, being more porous, has furnished a channel for the circulation of the heated solutions expelled from the cooling granite.

About 300 yards southeast of Brema bridge, an old tunnel, said to have been opened in prospecting for iron, exposes the rock along the east side of the quartzite. Near the schist the quartzite contains numerous garnets, and the quartz appears to be completely recrystallized. Adjoining the quartzite there is a bed of highly garnetiferous rock, 4 to 12 feet wide, which grades into the typical knotted schists. The strike of the schists is N. 23° E. and the dip practically vertical.

The altered rock (Spec. 456) near the quartzite is dark gray to brown in color, and consists of numerous red garnets, ranging up to 4 mm. in diameter, fine-grained quartz, radiating crystals of dark gray sillimanite, and a little dark green chlorite. Examined in thin sections under the microscope the garnets are light pink to nearly colorless, contain numerous inclusions, are irregular in outline, and show partial alteration to chlorite

in their border portions and along fractures. Some are quite clear while others are rendered almost opaque by clouds of dust-like inclusions (magnetite or hematite), which are frequently confined to the central portions leaving the borders clear. Some of the garnets also contain numerous included quartz grains. Quartz, which is the second mineral in relative abundance, has been completely recrystallized and occurs in irregular grains showing strain shadows. The sillimanite is mostly arranged in radiating clusters of prismatic crystals. Magnetite, hematite, and a little pyrite are present as minor accessories.

Other exposures are furnished by several surface pits located along the same line of strike, a mile southwest of New Canton; and here the garnet rock may be seen grading on the east into the knotted schists containing scattered eyes of garnet. The rock (Specs. 465 and 466) from these openings is dark reddish-brown in color and consists chiefly of garnets with less quartz, sillimanite, cyanite, chlorite, magnetite, hematite, and pyrite present in the order named. The garnets (almadite) are large, imperfectly formed, and contain numerous inclusions of quartz and iron oxide. Under the microscope they frequently show irregular branching radii of clear mineral which spread out from the center and separate areas that are full of inclusions. As these radii recede from the center they branch into a vein-like network, which grades without definite boundaries into the surrounding ground-mass, consisting of quartz, garnet, and magnetite. Another form of garnet (possibly spessartite) is so full of dust-like inclusions of magnetite with a little quartz, that they are rendered almost opaque. These inclusions show a zonal arrangement, and in some of the garnets the zonal bands are broken and contorted as though by crushing. Sillimanite is present in radiating groups of fine-bladed crystals, and cyanite occurs in large-bladed prisms, which frequently show multiple twinning and contain dust-like inclusions of iron oxide.

A garnet-sillimanite rock, similar to that just described, outcrops along the road near Hatcher Creek, a mile south of Gravel Hill postoffice, and also near the summit of Tower Hill, $2\frac{1}{2}$ miles southwest of Gravel Hill.

Passing eastward from the quartzite, knotted schists are exposed in the river bluffs for several hundred yards. Specimen 307, taken from an outcrop 200 yards east of the quartzite and 800 yards from the contact, contains numerous eyes of biotite and only occasionally a small garnet. A detailed petrographic description of the rock is given on pages 32-33. About 300 yards farther east the schist (Spec. 306) is light bluish-gray in color, slightly coarser grained, and contains scattered eyes of garnet 1 to 2 mm.

in diameter. Specimen 305, taken about 400 yards from the contact, is of light gray sericitic schist containing garnets 2 to 4 mm. in diameter, and occasional flakes of biotite about 1 mm. in diameter.

Near Phelps Creek and about 300 yards from the contact hornblende begins to be plentiful in the schist, occurring in dark green crystals that range from small grains up to prisms 3 or 4 mm. in length. The rock (Specs. 303 and 304) is mostly fine-grained and compact, breaking readily along closely spaced joints. The minerals distinguishable megascopically are quartz, hornblende, chlorite, sericite, much pyrite, and a little magnetite. The New Canton copper mines are located directly in line of strike with these rocks and therefore the large amount of pyrite present is significant. Petrographic descriptions of rocks from the different copper mines are given on pages 250-256.

Near the second railroad bridge over Phelps Creek and about 250 yards from the contact the schist (Spec. 301) is a fine-grained, dark greenish-gray rock, speckled with numerous, well-formed, red garnets 0.5 mm. in diameter, and containing occasional lenses of pyrite 2 or 3 cm. in length. With the aid of a pocket lens small needles of hornblende, oriented parallel to the schistosity, and fine-grained quartz are seen to make up the greater part of the rock-mass. At the Margaret mine and about the same distance from the contact a quartzitic rock was found which contains irregular crystals of dark green hornblende and light greenish-brown needles of sillimanite.

In the bluff on the east side of Phelps Creek, and about 150 yards from the contact line shown on the map (Fig. 2), an apophysis or dike from the granite is exposed. It is perhaps 20 feet in width and parallels the inclosing schists in strike and dip. The rock (Spec. 426) is light gray in color, fine-grained, and highly schistose; it is composed essentially of white feldspar, quartz, and flakes of black biotite, which are oriented parallel to the schistosity and are much more plentiful in some portions of the rock than in others. A little garnet and magnetite may also be distinguished megascopically. Examined microscopically the rock is seen to be slightly porphyritic in texture, containing feldspars that range up to 2 mm. in length. The feldspars are all plagioclase (albite-oligoclase or oligoclase) and are for the most part unstriated, but occasionally both Carlsbad and albite twinning can be distinguished. The biotite is light greenish-brown in color, strongly pleochroic, and some of the flakes are nearly as large as the feldspars. The ground-mass is composed of feldspar, quartz, biotite, a little chlorite, small pink garnets, and a few grains of magnetite and irregular zircons.

Along the contact between the granite dike and the hornblende schists there is a layer of rock (Spec. 427), only a few inches thick, composed largely of bright green chlorite and well-formed garnets ranging up to 0.75 cm. in diameter. Under the microscope the garnets are seen to contain numerous inclusions of quartz and magnetite. None of the chlorite is derived from the garnets, for the latter are all fresh and unaltered. Quartz occurs in lenticular eyes and as small veinlets between the cleavage planes of the chlorite. Fluid inclusions, usually with bubbles, are plentiful and some are comparatively large. Scattered grains of magnetite and a little sericite make up the accessories.

About 50 yards southeast of the granite dike and within 100 yards of contact line shown on the map, the rock (Spec. 428) is light gray, fine-grained, close-textured, and distinctly schistose. It contains well-formed pink garnets ranging up to 2 mm. in diameter, and with the aid of a pocket lens small needles of green hornblende, quartz, and much fine-grained magnetite may be distinguished.

Under the microscope the magnetite is seen to occur in idiomorphic grains which are scattered through the rock without reference to the other minerals; the hornblende occurs in slender needle-like prisms, occasionally showing sections with crystal outline; and the quartz is present in irregular grains filling the interstices between the other minerals. Scattered through this ground-mass there are a few comparatively large irregular crystals of acid plagioclase feldspar, ranging up to 2 mm. in diameter. They are very ragged in outline and poikilitic in texture containing numerous small inclusions of quartz and to a lesser extent of the other minerals. The hornblende needles occasionally project into the feldspars, but are usually pushed aside by them. The feldspars are partly oriented with their greater elongations parallel to the schistosity, they rarely show fine albite twinning, and are usually unstriated. A little chlorite is present as an alteration product of hornblende.

The rock (Spec. 429) 30 yards south of that last described is dark green, even-granular, and more nearly massive in texture. Under the microscope it is seen to consist of hornblende, feldspar, quartz, and a little magnetite and pyrite, in the order named. Hornblende, which is dominant, occurs in irregular, elongated prisms only partly oriented parallel to the schistosity. The feldspar is all acid plagioclase with an index of refraction approximately the same as quartz, and is partly unstriated and partly twinned after the albite law. A small amount of chlorite is present as a secondary mineral. In the absence of chemical analyses it is impossible to say whether the rock is sedimentary or igneous in origin.

The rocks exposed in the bluffs along the east side of Phelps Creek as far south as the county road are all hornblende schists varying slightly in coarseness of texture. In places narrow dikes of quartz porphyry containing much biotite are interleaved with the hornblende schists.

About 60 yards northeast of the road bridge, and within 50 yards of the contact as shown on the map, the rock (Spec. 433) is dark green, fine-grained, close-textured, and contains much pyrite in scattered cubes, ranging up to 3 mm. in diameter. Examined microscopically the rock is seen to consist of quartz, hornblende, magnetite, a little plagioclase feldspar, and some secondary chlorite. The magnetite is present in idiomorphic grains evenly distributed through the rock; the hornblende is almost as plentiful as the quartz, occurring in needle-like prisms that are imperfectly oriented parallel to the schistosity; and the quartz fills the interstices between the other minerals and occasionally forms lenticular eyes, 1 mm. in diameter. Both hornblende and magnetite are present as inclusions in the quartz. A little acid plagioclase showing albite twinning may be identified in places but is not plentiful.

Specimen 434 was obtained from the bluffs facing the low ground on the south side of James River and about 75 yards east of the line of contact as shown on the map (Fig. 2). The rock is a dark gray, fine-grained hornblende schist containing streaks due to elongated segregations of the light-colored minerals. It is cut by closely spaced joints, which cause the rock to break into small rhombic shapes. Examined under the microscope, hornblende is seen to be dominant, occurring in slender prisms which occasionally show idiomorphic cross sections and are usually oriented parallel to the schistosity. They show good cleavage and are practically free from inclusions. The interstitial spaces are filled with acid plagioclase, quartz, and magnetite. The feldspars are clear, seldom show cleavage or twinning, and have an index of refraction slightly less than balsam, corresponding to albite or albite-oligoclase. Quartz is present as a minor constituent, magnetite occurs in small scattered grains, and there is a little chlorite present as an alteration product of hornblende.

A hundred yards farther east the hornblende schist (Spec. 435) is much coarser in texture. It is a heavy rock, dark green to black in color, and contains hornblendes ranging up to 6 mm. in diameter, numerous grains of magnetite, and occasional light-colored spots, consisting of fine-grained, light green epidote. Under the microscope the hornblende, which makes up the greater portion of the rock, is strongly pleochroic in shades of dark green, blue, and greenish-brown; it has good cleavage but poor

crystal form, and frequently contains numerous inclusions of quartz and magnetite. Magnetite is the second mineral in relative abundance, occurring in small angular grains and in larger masses which occasionally contain inclusions of hornblende. Epidote is present in small grains and granular aggregates, almost colorless and only slightly pleochroic. Quartz is sparingly present in small grains and chlorite occurs as an alteration product of hornblende.

Fine-grained hornblende schist, over 100 yards in width, intervenes between the coarse-grained schist and the granite, which first appears about 400 yards east of the line showing the approximate contact between the sedimentary and igneous rocks. In the road half a mile south of New Canton a coarse-grained hornblende schist, containing a much larger percentage of feldspar than the rock described above, is exposed close to the granite.

The granite (Spec. 438), exposed in the river bluffs near the hornblende schists, is dark gray, fine-grained, and very gneissic in structure. The minerals recognizable megascopically are feldspar, quartz, biotite, many small pink garnets, and a few scattered grains of hornblende and magnetite. A specimen (439) obtained about 200 yards farther east is much lighter in color. It has well-developed gneissic banding, and sericite is very prominent, while biotite is relatively scarce. Examined microscopically it is seen to consist of acid plagioclase, quartz, sericite, biotite, garnet, a very little hornblende, and the secondary minerals epidote and chlorite. There seems to be no potash feldspar present. Other specimens of the granite from this vicinity are described on pages 71-72.

On the opposite side of James River the marginal belt of hornblende schist is narrower, but there are several small elongated areas of hornblende schist included within the granite. Continuing northeast along the contact the belt of hornblende schists gradually becomes narrower and a short distance south of Fork Union entirely disappears.

RIVANNA RIVER SECTION ACROSS GRANITE CONTACT.

The contact between the granite and the sedimentary rocks is fairly well exposed in the bluffs on the south side of Rivanna River, a mile northwest of Carysbrook. A quarry has been opened in the granite within less than 100 yards of the contact, and the rock exposed in the opening is described in detail on pages 75-77. The contact can be located with an error of less than 20 feet, but there is little if any evidence of contact metamorphism. The granite is probably a little finer grained than that

exposed in the quarry, and contains more pyrite. The sedimentary rock is a chloritic slate which near the contact is slightly coarser grained, more siliceous, and less regular in its cleavage, but all of these differences may be due to other causes than contact metamorphism.

No evidence of faulting is visible, and the textural and structural relations of the slate indicate that it is older than the granite. The lack of pronounced evidence of contact action is probably due to the fact that the sedimentary rocks were intensely altered by dynamic metamorphism, prior to the intrusion of the granite, which must have been much cooler than the granite near New Canton. On pages 62-63 evidence was presented to show that the granite near Carysbrook was intruded and solidified at a later date than the granite farther south; and both the megascopic and microscopic evidence (see pp. 75-76) indicates that this granite was intruded in a partly solidified condition.

VEINS.

Quartz veins are of frequent occurrence in the sedimentary rocks near their contacts with the granite, and, where not exposed, their presence is commonly indicated by an abundance of quartz float on the surface. North of James River these veins contain soda-lime feldspars, muscovite, a little tourmaline and other minerals indicative of a magmatic origin, and they usually carry small quantities of gold; south of the river tourmaline is very abundant in many of the quartz veins. Some of the veins are accompanied by more or less metasomatic replacement of the wall rock, and an extreme example of this replacement is furnished by the sulphide bodies near New Canton. The walls of some of the veins show evidence of metamorphic action similar to that found near the granite contacts, but on a smaller scale. The gold-bearing veins are described in detail in chapter V.

WILLIS MOUNTAIN.

On the southwest slope of Round Mountain (the southern knob of Willis Mountain) the schists in the vicinity of an intrusive diorite show pronounced effects of contact action. The exposures are limited to two shafts 40 to 50 feet deep, located about 100 yards apart in an east and west direction, which were sunk in prospecting for copper. The size of the diorite body could not be ascertained because of the insufficiency of exposures, but the coarseness of texture indicates that it is probably large.

Megascopically the diorite (Spec. 390) is a massive dark gray rock composed essentially of dark green hornblende in irregular prismatic

crystals ranging up to 1.5 cm. in length, white feldspars, which frequently show multiple twinning, numerous red garnets about 1 mm. in diameter, with more or less pyrite and pyrrhotite. In places the rock is cut by narrow intersecting veinlets, some of which are composed of white feldspars, 2 to 3 cm. in diameter, with more or less pyrite and pyrrhotite, while others consist chiefly of white, even-granular calcite. The latter range up to 6 or 7 inches in thickness. There are also occasional streaks or bands due to the presence of unusual amounts of garnet, or, more rarely, epidote.

Examined microscopically the hornblendes are light green in color and contain numerous inclusions, principally feldspar and quartz. The feldspars show beautiful twinning after the albite and pericline laws, and in composition are probably intermediate between andesine and labradorite. Most of the garnets show good crystal form; they are slightly altered along fractures with the production of chlorite and calcite. A little light brown biotite, elongated grains of rutile, ilmenite partly altered to leucoxene, and occasional zircons make up the minor accessories.

The typical cyanite and quartz-sericite schists constituting Willis Mountain have been described in a previous chapter (see pages 25 and 27-28). The schist (Spec. 389) near the diorite is a light brown, fine-grained rock, heavily impregnated with pyrite in cubical crystals ranging up to 2 or 3 mm. in diameter. The other minerals recognizable megascopically are light brown biotite, a scaly micaceous mineral, colorless to light gray or green (probably chlorite), a few prismatic grains of rutile, and a little nearly colorless cyanite.

Under the microscope the light-colored mineral (chlorite), which is probably dominant, has very low interference colors and frequently occurs in radiating scales. The biotite is very light brown in color and rather weakly pleochroic; in places it contains needle-like prisms of rutile. Soda-lime feldspar, intermediate between andesine and labradorite, is the third mineral in relative abundance and frequently shows twinning after both the albite and pericline laws. Cyanite is quite plentiful, rutile is abundant in prismatic crystals and irregular grains, and there is also much calcite present. The crystals of pyrite contain occasional inclusions of rutile but no other minerals. Zircons are present as unimportant minor constituents.

OUTLINE OF GEOLOGICAL HISTORY.

The complete geological history of this region can not be written until the rocks of the Piedmont province have been studied and mapped in greater detail; the record is fragmentary and complex, and much of it

may never be deciphered. In the older rocks of the area, which have been classified as pre-Cambrian, no fossils have been found, and if they were ever present, they have probably been destroyed by the extensive metamorphism that has affected the entire region.

Pre-Cambrian.

The history of the James River basin in pre-Cambrian times is shrouded in much doubt. It is not known whether the period of igneous activity, resulting in the formation of the basic rocks of the greenstone area, preceded or followed the deposition of the pre-Cambrian sediments. These sediments were laid down as sand and mud in shallow waters not far from the shore, as is indicated by the lenticular shape and sudden pinching of many of the quartzite beds, as well as their frequent repetition. The formation of pure quartz sands involves the complete decomposition of quartz-bearing rocks in order that the quartz grains may be separated from the other constituents, the latter going to form the fine clayey beds. Therefore most of the sediments were probably derived from a low-lying land area mantled with residual decay. These conditions, however, did not continue uniformly throughout the entire period of sedimentation, for the arkosic beds lying between Lantana and Pryors Crossroads were laid down under conditions that did not permit mature weathering.

After their deposition the sedimentary beds were compressed by powerful forces acting in a northwest-southeast direction; the effects of which were close folding, faulting, mashing, and recrystallization. These great crustal movements, which brought the pre-Cambrian period to a close, converted a large area within the limits of the North American continent into land. While the crustal movements were still in progress, and probably as another manifestation of the same orogenic forces, large masses of molten rock were intruded into the sedimentary formations.

Cambrian.

The period of igneous activity, which resulted in the intrusion and differentiation of the granites and their related rocks, continued until after the great crustal movements had ceased. The formation of the gold veins is believed to represent the final stage in the differentiation and crystallization of the granite magma.

The massive diorite dikes, which occur at several places in the area, were probably intruded during Cambrian times, but after this there ensued a long period of freedom from igneous activity.

During Cambrian and early Ordovician time the area was subjected to extensive denudation, the products of erosion probably going to build up the Cambrian formations to the west. This period of denudation resulted in the removal of thousands of feet of overlying material and the exposure of the deep-seated granite.

Ordovician.

In late Ordovician time portions of the Piedmont region were again depressed below sea level to receive the sediments of that period, but it is improbable that all of the area has been under water since its elevation at the close of the pre-Cambrian. The Ordovician sediments were laid down on the eroded surface of the older formations, the material being derived from the neighboring land areas of pre-Cambrian rocks. The limited thickness of the coarser sediments at the base of the series, in comparison with the overlying beds of slate, indicates that subsidence was rather rapid; and the presence of tuffaceous beds shows that the movement was accompanied by more or less volcanic activity, although there are probably no igneous rocks of this age present in the district.

The Ordovician period was closed by marked geographical changes which enlarged the land areas and raised the recently formed sedimentary beds above water. After the close of the crustal movements resulting in the folding and faulting of the Arvonian slate belt, the region seems to have entered upon a period of quiescence. While oscillations occurred in other parts of the country, the Piedmont portion of Virginia seems to have remained above water and to have suffered little if any deformation until after the close of the Carboniferous; and during this entire period peneplanation continued uninterrupted.

Triassic.

It seems probable that the Piedmont peneplain was but slightly affected by the Appalachian revolution. The surface was warped or faulted sufficiently to form the elongated trough-like depressions, roughly parallel to the coast, in which the sedimentary beds of the Triassic (Newark formation) were laid down. It is not believed that these deposits ever covered a large area, though it is possible and perhaps probable that the detached areas found in Piedmont Virginia were once connected with one another. The prevailing red color of the formations, the presence of coal beds, and the character of the fossils indicate that the sediments were deposited in fresh or brackish water and that they are not of marine origin. The

material composing these strata was derived principally from the residual decay of the neighboring crystalline rocks, which must have undergone extensive chemical decomposition after they had been reduced by erosion to a nearly level plain.

The deposition of the Triassic sediments was accompanied or immediately followed by the intrusion of the diabase dikes, which are of frequent occurrence throughout the Piedmont area.

Since Triassic time the surface has been slightly elevated, and there has been a little faulting, but no important crustal movements have occurred; degradation has continued without interruption down to the present day. The detailed history of the development of the existing surface features is given in the chapter on physiography.

CHAPTER V.

THE GOLD MINES OF THE DISTRICT.

INTRODUCTION.

Detailed descriptions of all gold mines in the district are given below, but because of lack of information some of the descriptions are not nearly so complete as others. When the region was studied by the writer most of the mines had long been abandoned and consequently few openings were accessible; development work was in progress at the Scotia, Tellurium, Waller, and Young American mines; an old shaft was being reopened on the Payne property; and a little ore had recently been mined from superficial workings on the Bowles tract. Some of the older mines have been described from time to time by geologists and mining engineers, and wherever information could be obtained from such sources it has been freely used. The mines on the north side of James River, in Goochland and Fluvanna counties, will be considered first, and then those located on the south side of the river in Buckingham County.

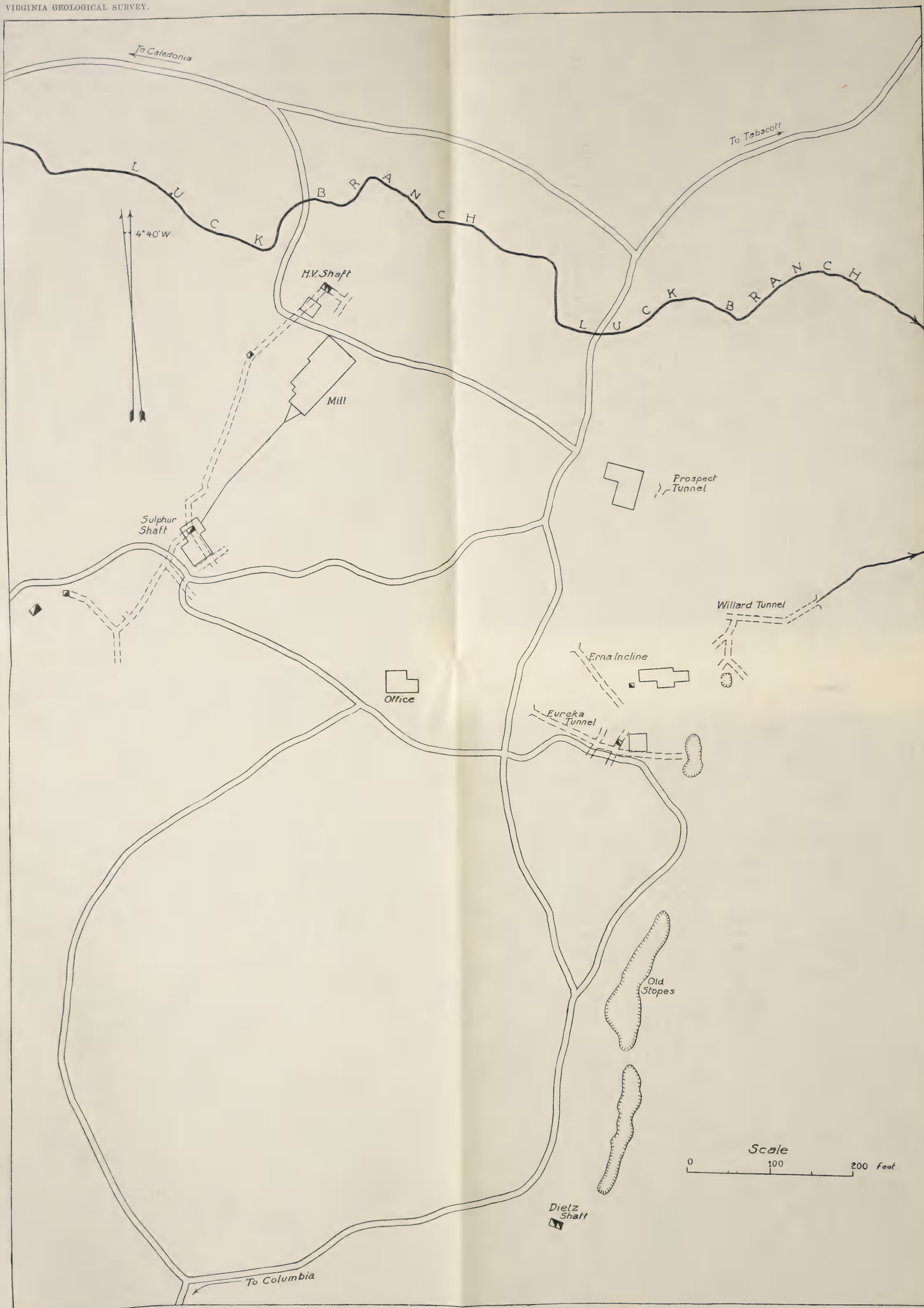
MINES IN GOOCHLAND AND FLUVANNA COUNTIES.

The Young American Mine.

Location.—The Young American gold mine is situated in Goochland County about $11\frac{1}{2}$ miles north of Lantana and $6\frac{1}{2}$ miles northeast of Columbia.

History.—The Young American, formerly known as the Gilmer mine, is said to have been discovered about 1869 by a Mr. Aldrich, who at that time was operating a saw mill on the property. After a little prospecting he sank a shallow shaft on a vein, now known as the "House" vein, and then built a small stamp mill to crush the ore. The mill had wooden stamp-stems with iron shoes, and was operated by the same engine that furnished power for the saw mill. Mr. Aldrich is reported to have made some money from the mine, but only worked it for a short time. Later gold was discovered in the branch that runs through the property and sluice and rocker washing was carried on during the period between 1871 and 1874.

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MAP OF SURFACE AND UNDERGROUND WORKINGS OF YOUNG AMERICAN MINE.

In 1880, the Tagus Gold Mining Company began development work and continued operations for three years. About 100 tons of ore found on the surface were hauled to the Belzoro mill and stamped, yielding a return of \$5.00 per ton. The "House" vein was developed and stoped down to water level for a distance of approximately 600 feet along the strike, and some small lenses of quartz, paralleling the "House" vein about 100 feet to the west, were exposed by an adit and mined. The "Sulphur" vein, about 300 yards west of the "House" vein, was explored, several small shafts sunk, and much of the vein above water level stoped out. A 4-foot Bryan mill was installed to pulverize the ore. As no records are now available it is impossible to give authentic information in regard to the production and average value of the ore mined. According to one report the average value of the ore obtained from the "House" vein was \$5.27 per ton, but another states that it averaged \$10.00 per ton. They all agree that the ore from the "Sulphur" vein was lower in value.

From 1885 to 1909, when the present company bought the property, the mine passed through several hands, and while occasional attempts at development were made, very little ore was milled. It is reported that a cyanide plant was in operation in 1893, but with what success is not known.^a The present company has reopened several of the old shafts and drives, sunk 2 shafts on the "Sulphur" vein to a depth of 84 and 100 feet, respectively, and done considerable development work, chiefly on the "Sulphur" vein. After making trial runs with the old Bryan mill, a new building was erected in 1910 and a Lane mill installed, but only about 1,500 tons of ore have as yet been milled.

Present equipment.—The mine is equipped with 2 shaft houses, a mill, and several other buildings. A steam hoist is located at each of the shaft houses, and there is an air compressor to furnish compressed air for the drills. The mill contains a Blake crusher, feeder, slow-speed Lane mill, and 2 Traylor concentrating tables.

Underground development.—The "Sulphur" vein, having a strike of N. 30° E., and an average dip of about 40° toward the southeast, is developed by 2 hoisting shafts and several air shafts, with underground drives that connect them and extend for a distance of 500 feet or more along the vein. The "Sulphur" shaft, sunk on top of the hill, in the hanging wall at a distance of 60 feet from the outcrop, is vertical to a depth of 80 feet where it intersects the vein, and then follows the vein on

^aNitze, H. B. C., and Wilkins, H. A. J., *Gold Mining in North Carolina and Adjacent South Appalachian Regions*, Bull. 10, N. C. Geol. Survey, 1897, p. 38.

an incline for about 42 feet, making the total depth below the surface 100 feet. About 75 feet from the surface, drives extend in either direction along the vein, connecting with the other shafts, and near the bottom of the incline 2 short drives run northeast and southwest. The "H. V." shaft, near the branch, 340 feet northeast of the "Sulphur" shaft, is vertical and 83 feet deep, the first 30 feet being on the vein, which here is nearly vertical for that distance. At a depth of 30 feet from the surface a drive along the vein connects with the "Sulphur" shaft, and 54 feet from the surface an 18-foot cross-cut running southeast intersects the vein, which at this point is further exposed by 2 short drives in either direction.

Practically all the stoping has been confined to the upper portion of the vein above the drive connecting the two hoisting shafts, and very little ore that would pay the cost of mining and milling remains in that part of the mine.

The "House" vein, outcropping about 250 yards east of the "Sulphur" shaft, is not at present accessible, but the old stopes and surface cuts have a strike of N. 22° E. A shaft, sunk about 350 yards southeast of the "Sulphur" shaft, did not strike the vein. Several adits have been driven under the hill near the north end of the old workings, and though they were not carried far enough to intersect the "House" vein, they expose a number of large lenses and stringers which approximately parallel that vein. The larger lenses encountered have been mined out above the water level.

General description of the geology.—There are almost no surface outcrops in the vicinity of the Young American mine, but there are many exposures along Big Byrd Creek, which cuts directly across the strike of the rocks, 3 miles southwest of the property. On the east side of the creek, about half a mile south of Bowles' bridge, rocks outcrop which are apparently identical with the country rock exposed in the underground workings of the mine, and they are in the same line of strike. These rocks are intensely metamorphosed schists and gneisses, derived from bedded sedimentaries, which were probably arkosic sandstones and grits. About three-quarters of a mile southeast of the mine this series of altered sedimentary rocks passes into and is interbedded with quartzites, which are in places highly ferruginous, containing both specular hematite and magnetite. Crystals of magnetite, consisting of octahedrons 1 cm. and less in diameter, which have weathered from the underlying rock, are found on the surface 300 yards northeast of the veins, and at several other localities on the property and in its immediate vicinity. The wall rock exposed in the mine usually contains much fine-grained magnetite.

The hornblendic border facies of the main granite batholith is exposed about a mile southeast of the mine, and what is probably a tongue from the latter comes within three-quarters of a mile or less, outcrops of granite occurring along the branch that runs about that distance northeast of the mine.

Two varieties of gneiss are exposed in the underground workings: The dominant type is a dark greenish-gray, fine-grained rock, usually banded, and composed essentially of quartz, feldspar, hornblende, biotite, and chlorite, with smaller amounts of magnetite, calcite, and sericite; the other, which is similar except for the absence of most of the iron-bearing silicates, is a fine-grained, light gray rock, composed essentially of quartz, feldspar, sericite, and smaller amounts of chlorite and calcite. The chief mineral constituents in these rocks, while varying somewhat in their relative proportions, are always the same.

In the openings on the "Sulphur" vein, the light-colored gneiss occurs as a bed, varying from $1\frac{1}{2}$ to 8 feet in thickness and lying between strata of the darker gneiss. It was also found on the dumps of some small pits and shafts near the line of strike of the "House" vein, about 200 yards south of the Dietz shaft, but in most openings on the property that are now accessible the dark hornblendic rock is the variety exposed.

There are two principal veins on the property that have been worked for gold, the "Sulphur" and the "House" veins. In the vicinity of the "House" vein there is a large number of small stringers and lenses which have been mined to a limited extent.

The "Sulphur" vein at the surface has an average strike of about N. 40° E., which is approximately the same as that of the country rock, but locally there is considerable variation, and in the underground workings near the Chittenden air shaft there is a sharp change in strike from N. 21° to 53° E. The dip is toward the southeast, changing from almost vertical in places near the surface to an angle of 30° in some of the lower workings, the average for the first 150 feet from the outcrop being about 50° . The width varies from 6 feet down to a few inches, and the average is probably between 2 and 3 feet. Where the vein is several feet wide it consists of a single mass of quartz, but elsewhere it frequently breaks up into a number of approximately parallel stringers and lenses, forming a belt 6 or 7 feet wide in which the country rock between the veinlets may be more or less mineralized. (See figs. 6 and 7.) In one instance noted, the veinlets instead of being parallel to the general inclination of the vein cut across it in such way as to suggest their formation in

a zone of shear faulting (see fig. 9, p. 130). Where exposed in the underground workings, the "Sulphur" vein occurs in the light-colored gneiss and also in both the overlying and underlying, dark, hornblendic gneiss.

The "House" vein, 200 to 300 yards east of the "Sulphur" vein, has a strike of about N. 22° E., which would cause the two veins to intersect if they both maintain their courses toward the northeast. The "House" vein is said to have an average width of 5 or 6 feet, but as the old workings have caved and are not now accessible this statement could not be verified. The strike was determined by means of the old surface cuts and caved stopes along the outcrop. Near the southwestern end of the old workings the country rock seems to be chiefly the light-colored gneiss or schist, but where the adits have been driven under the hill near the northeastern extension of the vein, the country rock, wherever exposed, is a dark green hornblendic gneiss, similar to that found in the openings on the "Sulphur" vein.

The adits, above mentioned, were not carried far enough to strike the "House" vein, but they cut through a large number of lenticular veinlets that apparently parallel the main vein. These veinlets range from stringers a fraction of an inch in width up to lenses 2 feet thick and 25 feet or more in length, and are pegmatitic in character, frequently carrying much plagioclase feldspar—a mineral which is only occasionally present in the "Sulphur" vein. No openings have been made much below water level, but where the lenses have been mined their dip is practically vertical.

While the veins and country rock at the Young American mine are much broken by jointing, and there is in places a small amount of faulting along these joints, there is no evidence of important faulting since the formation of the veins. The irregularities in the strike and dip which were mentioned above are believed to be due to faulting and fracturing prior to the formation of the veins, which left openings or lines of weakness along which the solutions that deposited the ores were able to penetrate.

In addition to the veins described above, several quartz veins carrying considerable tourmaline outcrop in the vicinity of the mine, but at the surface they contain only traces of gold and therefore practically no development work has been done on them.

Detailed descriptions of the veins and wall rock.—At the bottom of the incline from the "Sulphur" shaft, about 100 feet from the surface and 65 to 75 feet below the natural water level, the vein consists of lenses and irregular masses of quartz distributed over a belt 5 to 6 feet in width, which is here confined to the bed of light-colored gneiss. A sketch, drawn to scale,

showing the distribution of vein quartz and the structural relations of the wall rock, is given in fig. 6. Only a short distance above this point the quartz begins to collect together so as to form a single well-defined and continuous vein.

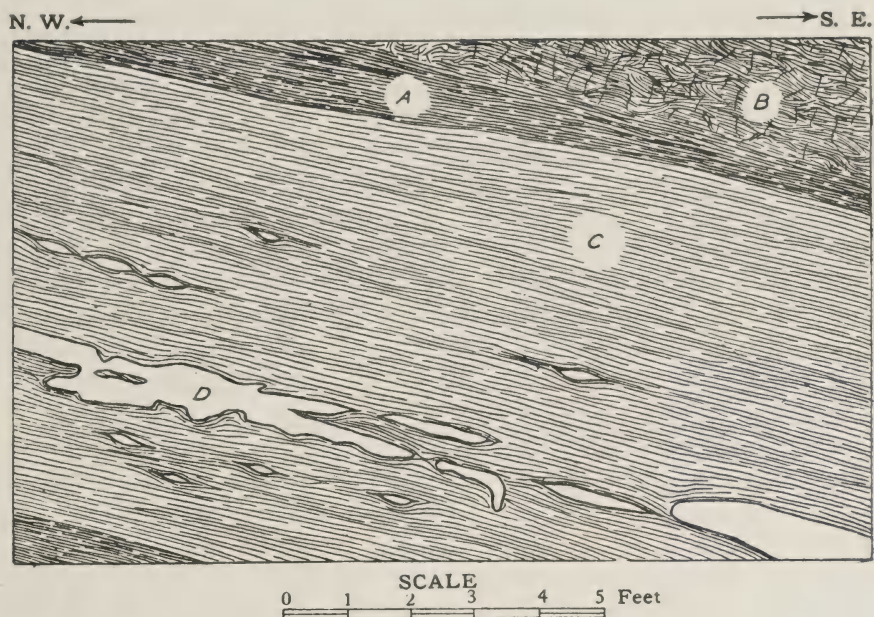


Fig. 6.—Vertical section showing vein at bottom of "Sulphur" incline, Young American Mine. A, dark-colored gneiss; B, partly decomposed gneiss; C, light-colored gneiss; D, vein quartz.

The vein quartz is white, translucent and coarsely crystalline. It contains a little over 1 per cent. of pyrite, slightly cupriferous and sometimes associated with fine-grained magnetite, and, rarely, crystals of white feldspar difficult to distinguish from quartz are present. In places there are small masses of chlorite and flakes of biotite which probably represent altered inclusions of country rock. A carefully collected, average sample assayed \$1.34 in gold with no silver. In the vicinity of the quartz masses, the gneiss is also mineralized to a considerable degree, containing disseminated grains of pyrite and many small veinlets of quartz which decrease in number and size on passing away from the vein stringers, so that they are not noticeable at a distance of 4 or 5 feet. These veinlets range from half an inch down to those that are microscopic in size and usually

parallel the schistosity; the pyrite occurs in small grains and elongated masses less than 1 cm. in diameter and is frequently more plentiful along the quartz veinlets.

The dark-colored gneiss overlying the bed of lighter color, while apparently fresh near the contact, passes gradually into partially decomposed rock a short distance above (see fig. 6), and this illustrates the great depth to which weathering has reached in this area. As this was the deepest opening accessible in the area when the region was studied by the writer, average samples of the different rocks exposed at this point were carefully taken. A partial analysis of the vein quartz was made, and complete analyses of the two varieties of gneiss and also of the partly decomposed gneiss. For convenience in comparison these analyses are assembled in the table given below, which is followed by a detailed petrographic description of the rocks. The analyses are arranged in the order of their relative distance from the vein quartz, which is also the order of decreasing mineralization as is indicated by the decreasing percentages of SiO_2 and FeS_2 .

Analyses of vein and wall rock from the Young American Gold Mine.

	I	II	III	IV
SiO_2		75.72	66.69	63.68
Al_2O_3		13.14	15.25	16.11
Fe_2O_3		0.33	1.46	4.05
FeO		1.44	3.78	2.67
MgO		0.31	2.89	3.55
CaO		1.07	2.33	2.18
Na_2O		3.77	3.56	3.75
K_2O		1.75	1.65	1.43
$\text{H}_2\text{O}-$		0.12	0.33	1.07
$\text{H}_2\text{O}+$		1.00	1.26	0.96
TiO_2		0.10	0.41	0.46
ZrO_2		0.01	.....	.....
CO_2		0.63	0.36	.....
P_2O_5		0.04	0.06	0.06
S				Trace
Cr_2O_3				0.01
V_2O_5				0.01
MnO		0.02	0.09	0.08
BaO		0.02	.....	.....
Li_2O		Trace	Trace	Trace
Cu	Trace	Trace	Trace	Trace
FeS_2	1.13	0.62	0.09	Trace
Gold (ounces)	0.065	Trace	Trace	Trace
Silver (ounces)		Trace	.....	.....
		99.99	100.21	100.07

- I. Vein quartz (*D* in fig. 6). This sample contained 0.87 per cent. iron in excess of the amount necessary to form pyrite, the excess being present as a constituent of magnetite and chlorite. Determinations made by E. E. Burlingame and Co.
- II. Light-colored gneiss (*C* in fig. 6). Analysis made by Roger C. Wells; gold and silver determined by E. E. Burlingame and Co. Another sample of this rock assayed by the writer gave 0.05 oz. of gold per ton.
- III. Dark-colored gneiss (*A* in fig. 6). Analysis made by Roger C. Wells; gold and silver determined by the writer.
- IV. Decomposed dark-colored gneiss (*B* in fig. 6). Analysis made by Roger C. Wells; gold and silver determined by the writer.

The dark-colored gneiss is gray, and in places has a slightly greenish tinge. It is fine-grained, even-granular, and the minerals are imperfectly segregated into parallel bands 1 mm. or less in width, which are frequently folded or contorted to a small extent. The dark bands are due to the presence of biotite, chlorite, hornblende, and magnetite; the light bands are composed chiefly of quartz with a little sericite. Pink garnets, about 2 mm. in diameter, more or less crushed and elongated parallel to the schistosity, occur scattered through the rock, and a little pyrite may also be distinguished.

Examined microscopically, the rock (Spec. 112-A) has a well-defined schistose structure, the different minerals being oriented parallel to their greatest elongation, and largely segregated into bands which differ from one another in size of grain as well as in mineral composition. In the order of relative abundance the minerals present in the slide are quartz, feldspar, biotite, chlorite, hornblende, magnetite, carbonate (calcite ?), pyrite, and sericite. The quartz grains are usually clear, show no optical distortion, and contain occasional rutile needles, and other minute inclusions. Some of the larger bands consist almost exclusively of quartz, the individual grains of which they are composed being slightly larger than those in the rest of the rock. These bands are probably chiefly due to the recrystallization of silica originally present in the rock, but may be formed in part from quartz brought in by the vein-forming solutions. Much feldspar (probably oligoclase) is present in the slide. It is partly kaolinized, seldom shows twinning, and, as the index of refraction is practically the same as quartz, is hard to distinguish from the latter. The biotite is light brown to greenish-brown in color, strongly pleochroic, and frequently shows partial alteration to chlorite. There is much chlorite present, occasionally showing multiple twinning, and it appears to have been derived chiefly from the hornblende. Hornblende occurs in two varieties; one light green in color, the other light brown to nearly colorless. It is extensively altered with the formation of carbonate (calcite ?) and chlorite. In places numerous fragments of hornblende occur,

separated and completely surrounded by calcite, which extinguish simultaneously under crossed nicols, showing that all of the fragments belong to a single crystal which has undergone partial alteration. Much fine-grained magnetite is present and occasionally a little pyrite.

In the chemical analysis, the excess of magnesium over calcium indicates that the rock is sedimentary in origin, and this is confirmed by the structural relations. Chemical analysis as well as microscopic examination shows that weathering has begun to affect the rock even where freshest. In comparing the analysis of the freshest material with that of the partly decomposed rock, it is seen that the chief changes, aside from kaolinization of the feldspars, have been the removal of carbonate and the oxidation of much of the ferrous iron to the ferric condition.

As the light-colored gneiss at this point is nearer to the quartz stringers than the darker gneiss, it contains more quartz veinlets and a larger amount of pyrite. The rock (Spec. 112-C) is white to light gray in color, and distinctly banded, though this feature is not as noticeable as in the darker gneiss, because of the lack of contrast in the colors of the principal constituents—quartz, sericite, and feldspar. The bands are frequently contorted, especially in the vicinity of the quartz stringers and lenses. The small veinlets of quartz, ranging up to about 1 cm. in diameter, are usually parallel to the banding, but in places cut directly across. Pyrite occurs in grains and small lenticular masses elongated parallel to the schistosity, is sometimes associated with magnetite, and is more plentiful in the vicinity of the quartz veinlets. A little chlorite, occasional pink garnets, crushed and elongated parallel to the schistosity, and very rarely needles of black hornblende, make up the minor constituents which are recognizable in the hand specimen.

Microscopic study shows that the principal mineral constituents in the order of their relative abundance are quartz, sericite, feldspar, chlorite, and carbonate (calcite?). The textural characteristics and mineral composition of the rock are similar to the darker gneiss (112-A) excepting that quartz and sericite are more abundant, while biotite and hornblende are essentially absent. The minerals, particularly sericite, are largely segregated into parallel bands. The feldspars are not so extensively kaolinized as in the overlying rock, but appear to be similar in composition. They are seldom striated and have an index of refraction only a little below quartz, indicating that they are probably near albite-oligoclase in composition. Orthoclase is rare if present, and probably most if not all of the potash content is in the form of sericite. An analysis of this rock is given in column II of the table on page 124.

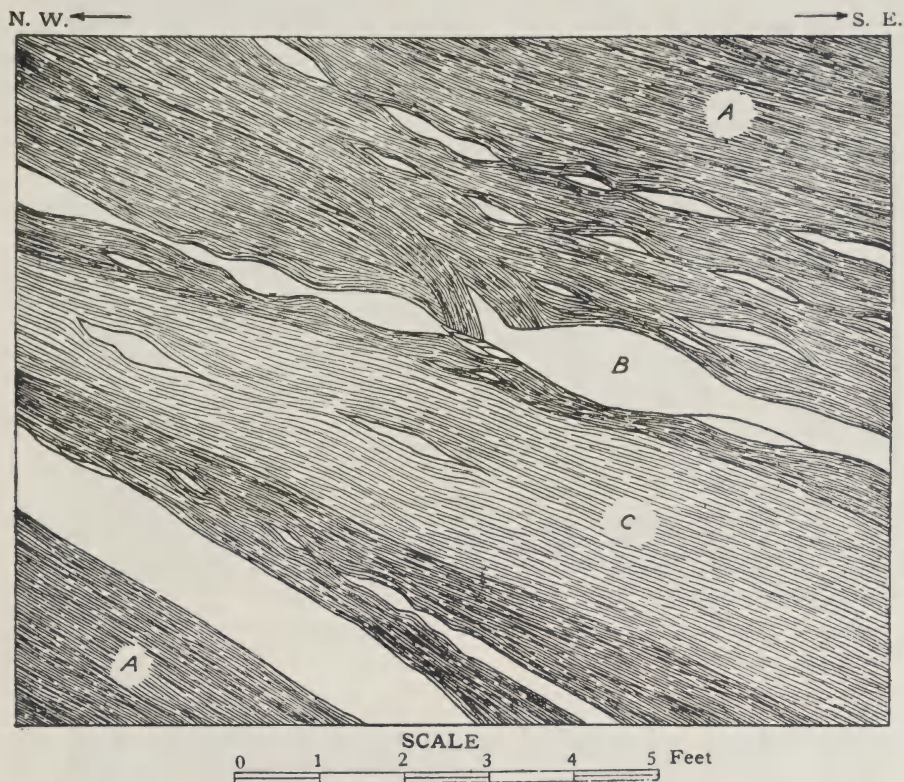


Fig. 7.—Sketch showing distribution of vein quartz in light- and dark-colored gneisses at the Young American Mine. *A*, dark-colored gneiss; *B*, vein quartz; *C*, light-colored gneiss.

The sketch shown in fig. 7 indicates the appearance of the face in the drive running southeast near the bottom of the "Sulphur" incline. The location is about 10 feet above the sketch shown in fig. 6, and 18 feet southeast. Here the bed of light-colored gneiss is thinner, and the vein quartz chiefly distributed in the overlying and underlying gneiss. The quartz vein, about a foot wide, shown in the lower left hand corner of the sketch, contains chalcopyrite as well as pyrite. Mr. Knutzen, Superintendent of the Young American mine, states that samples from this 1-foot vein yielded from \$11.20 to \$24.00 gold per ton, and that a picked specimen showing chalcopyrite carried \$50.00 per ton. The value of the ore in this drive seems to vary greatly within short distances; an average sample, obtained from 6 buckets (about $11\frac{1}{2}$ tons) after passing through the crusher, assayed \$8.00, while a similar sample from 4 buckets of ore

that were obtained as a result of the next round of blasting gave only \$1.00 per ton. According to Mr. Knutzen the gold content is highest where chalcopyrite is found.

A hand specimen (116) was obtained from this drive showing the two varieties of gneiss in contact. The line of contact is quite sharp and is parallel to the banding which is slightly contorted. The rock is cut by narrow veinlets of quartz commonly parallel to the banding and in places showing a tendency to follow the contact between the light and dark gneiss, but which frequently cut directly across the schistosity. A thin section was made to show one of these veinlets about 0.5 cm. in width. Under the microscope, numerous liquid- and gas-filled cavities can be seen in the quartz, usually arranged in rows or planes that occasionally pass without interruption from one crystal individual to another. Some of the cavities contain bubbles in constant and rapid vibration. The dark variety of gneiss, which in the slide forms the walls of the veinlet, is similar to that described above. The constituent minerals are quartz, feldspar, biotite, hornblende, chlorite, sericite, and calcite, and a little pyrite, magnetite, and ilmenite partly altered to leucoxene. A small colorless garnet, showing slight anomalous biaxial character, is also present in the slide. In several places pyrite occurs, bordered by a narrow rim of magnetite, which was probably produced under conditions of partial oxidation.

The smaller veinlets, especially in the light-colored gneiss, show a strong tendency to form lenses, but they are not as perfectly developed as those in the "Middle" vein at the Tellurium mine. A photograph of some small lenses in light-colored gneiss from the "Sulphur" shaft is shown in Pl. X, fig. 2.

Pyrite is more plentiful in the light-colored gneiss than in the dark variety, and occurs in elongated grains or broken lines parallel to the banding. Some secondary pyrite was noted along joint planes in both the vein quartz and the country rock.

Near the bottom of the "Sulphur" shaft, about 80 feet from the surface and just above the incline, the quartz vein is 2 feet wide, and the dark gray, biotite-sericite gneiss, which forms the foot wall, is heavily impregnated with pyrite and contains occasional lenses and veinlets of quartz. Mr. Knutzen obtained assays of \$3.60 gold per ton from this mineralized wall rock, which extends several feet from the vein.

In Pl. X, fig. 1, is shown a photograph of one of the quartz veinlets in contact with the heavily mineralized gneiss. A crystal of light blue cyanite 6 mm. wide and 3 cm. long extends from the wall rock out into

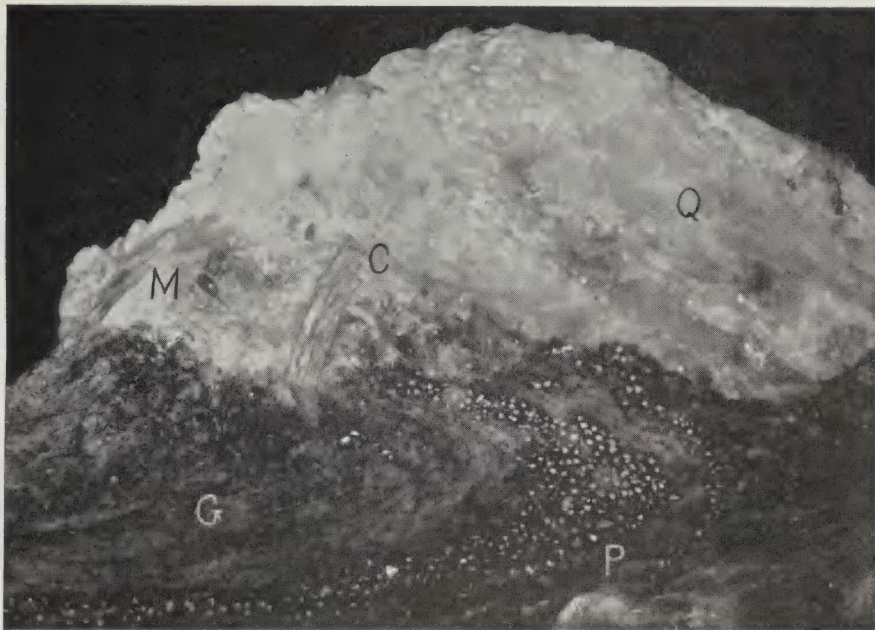


Fig. 1.—Photograph showing cyanite and muscovite in vein quartz from the Young American mine. *C*, cyanite; *M*, muscovite; *Q*, vein quartz; *P*, pyrite; *G*, gneiss.

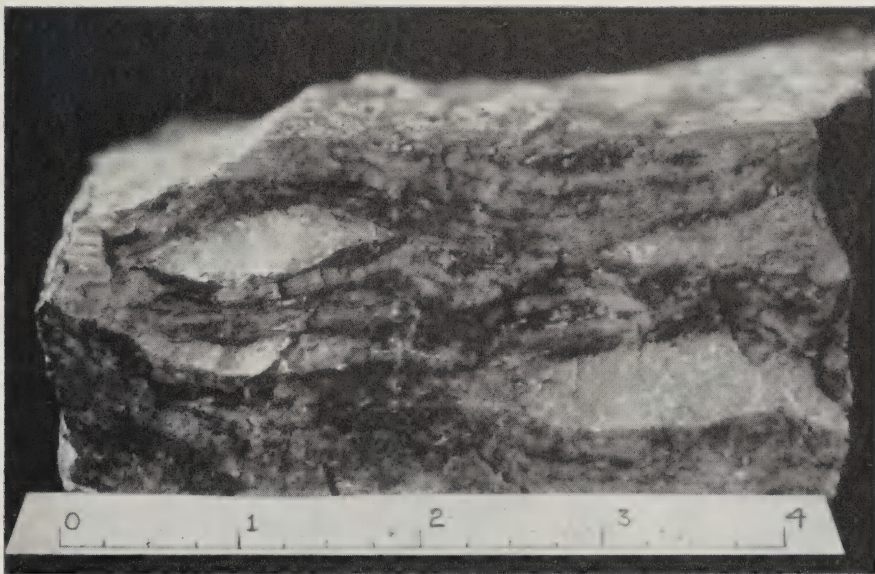


Fig. 2.—Lenses of vein quartz in gneiss from Young American mine.
CYANITE AND MUSCOVITE IN QUARTZ. AND QUARTZ LENSES IN GNEISS.

the quartz. The vein quartz also contains a little white feldspar, flakes of muscovite, and a few specks of chlorite. Calcite occurs in the gneiss and is partly concentrated along the contact with the veinlet. Very little pyrite is present in the quartz, but it is abundant in the gneiss, where it occurs in bands and broken lines parallel to the schistosity, which is much folded in the vicinity of the veinlet. Pieces of vein quartz, similar to that just described, but containing both cyanite and tourmaline, were found on the surface. The cyanite is sparingly distributed through the quartz in light blue prismatic crystals 3 to 4 mm. wide and 1.5 cm. long; and the tourmaline occurs in black prisms 2 to 3 mm. in diameter, which usually radiate in all directions from a common center. Elsewhere cyanite was noted in the metamorphosed wall rock near the veins, but in the specimens described above it occurs in detached prisms within the vein quartz itself.

In the foot-wall, 5 or 6 feet from the vein at the bottom of the "Sulphur" shaft, the rock is a dark gray, fine-grained, even-granular gneiss, with well-marked banding. It shows no evidence of mineralization, pyrite as well as the quartz veinlets being absent. The light-colored bands in the rock range up to 2 mm. in width and are composed chiefly of feldspar and quartz, though they are not as a rule distinguishable from each other in the hand specimen. The dark bands are narrower and consist essentially of biotite, hornblende, and chlorite. Much magnetite is present in small grains, but no garnets were noted. Under the microscope the rock is similar to the dark variety of gneiss described on pages 125-126, except that feldspar seems to be dominant over quartz, possibly because of the absence of silicification by vein-forming solutions. In the order of their relative abundance the minerals present are feldspar (probably andesine or oligoclase-andesine), quartz, hornblende, biotite, chlorite, calcite, and magnetite, with a few scattered grains of zircon and titanite. The hornblende occurs in two varieties, one green in color, and the other yellowish-brown. The latter, which is subordinate in amount, has parallel extinction and is present in long ragged prisms. It is one of the orthorhombic amphiboles. The other minerals present no unusual characteristics.

The drive connecting the "Sulphur" and "H. V." shafts exposes an offset of 10 to 15 feet in the course of the vein just north of the "Sulphur" shaft, the space between being occupied by a zone containing numerous lenses and irregular masses of quartz. At the shaft the vein is standing nearly vertical. The sketch given in fig. 8 shows the distribution and shape of the quartz masses exposed on the east side of the drive about 15 feet north of the shaft. The country rock here is the dark variety of gneiss, and is much folded and contorted.

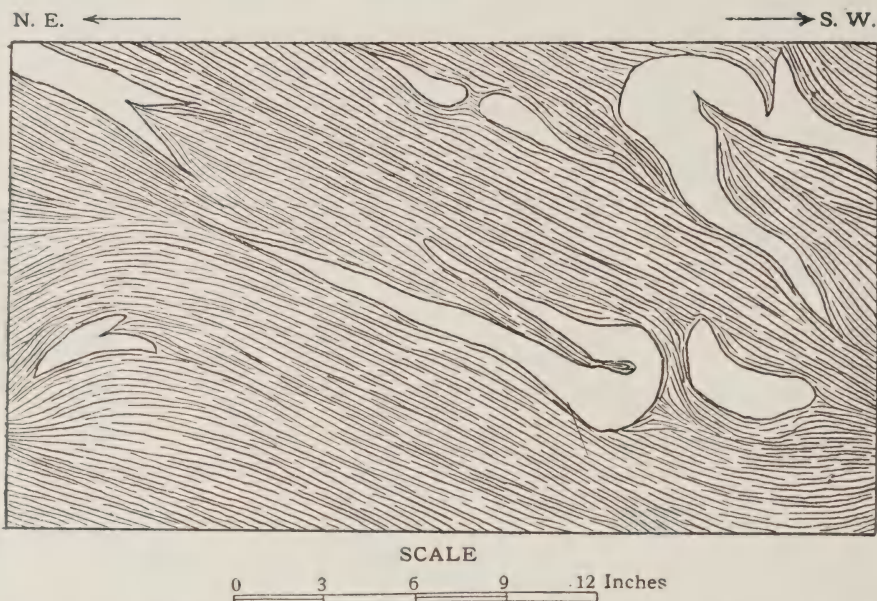


Fig. 8.—Vertical section showing distribution of vein quartz in a sheared zone at the Young American Mine.

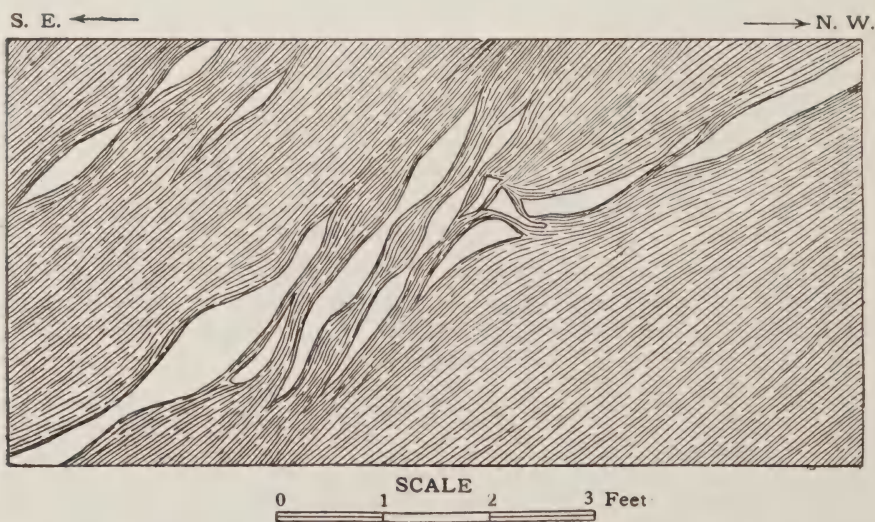


Fig. 9.—Sketch showing distribution of quartz lenses in a zone of shear faulting, Young American Mine.

There is another sharp break in the course of the vein near the Chittenden shaft where the strike suddenly changes from N. 21° to 53° E., and at this point there is a similar breaking up of the vein into separate lenses and irregular masses. A sketch of the vein, exposed in a small opening opposite the Chittenden shaft, is given in fig. 9. The distribution of the quartz lenses relative to the average strike and dip of the vein suggests that they were formed in a zone of shear faulting. The country rock is the dark variety of gneiss which is slightly mineralized in the immediate vicinity of the vein. A sample from the hanging wall, assayed by the writer, gave 0.03 ounces gold per ton. A 12-ton mill run of mineralized gneiss from the foot-wall of the vein, in the main drive about 40 feet northeast of this place, is said to have averaged \$3.60 gold per ton.

In the "H. V." shaft, the vein is nearly vertical to a depth of 30 feet, at which point it begins to dip toward the southeast and leaves the shaft. (See fig. 10.) Where the vein is exposed by the cross-cut from the shaft, 54 feet below the surface, it is 3 to 6 feet in width, dips at an angle of 40° toward the southeast and has a strike of about N. 30° E. The wall rock on both sides of the vein is the dark variety of gneiss, much decomposed, and showing no evidence of mineralization, but Mr. Knutzen states that a sample from the hanging wall assayed \$0.50 per ton. The vein quartz is irregularly mineralized, containing pyrite, chalcopyrite, and occasionally a very little sphalerite.

The sulphides are strung out in narrow lines or small lenticular masses approximately parallel to the walls, and the sphalerite usually occurs separate from the other ore minerals instead of being intermixed with them. A little white feldspar occurs in some of the quartz, but appears to be chiefly confined to the border portions of the vein. Very rarely, black tourmaline is present in small radiating prisms, and one specimen was found with a speck of free gold about 0.4 mm. in diameter, resting on the tourmaline, which is imbedded in quartz and surrounded by a small amount of limonite derived from pyrite. Pieces of the vein frequently show imperfect crystals of quartz lining joint planes, and several small vug-like openings were seen in which the walls were lined in a similar manner. It is probable, however, that these openings are due to the oxidation and removal of pyrite rather than to spaces that were left unfilled when the vein was originally formed. Some of these vug-like spaces contain a little pyrite, more or less oxidized, and in places the sulphide has a crystal form closely resembling marcasite. Small flakes of chlorite and muscovite occur in parts of the vein.

The gold is not evenly distributed throughout the vein, much of it being apparently concentrated in the sulphides. Mr. Knutzen obtained an assay of 5.8 ounces of gold per ton from a piece of the chalcopyrite. A mill run made on 8 tons of ore from the vein at this point averaged \$3.20 per ton.

The "H. V." shaft passes through the bed of light-colored gneiss about 15 feet below the cross-cut to the vein. At this point it is 3 to 4 feet thick

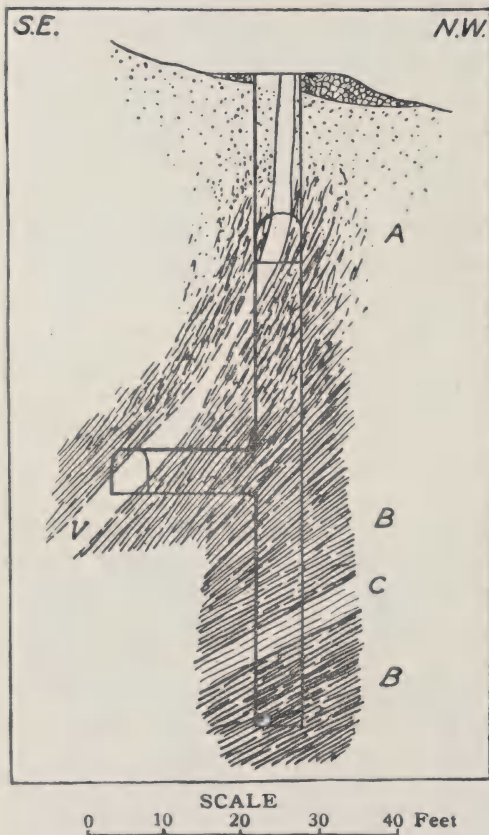


Fig. 10.—Vertical section through "H. V." shaft, Young American Mine. V, vein; A, decomposed gneiss; B, dark-colored gneiss; C, light-colored gneiss.

and dips towards the southeast at an angle of about 25° (see fig. 10). The rock is white and highly lustrous on fracture surfaces parallel to the cleavage. In addition to the quartz and sericite, a little fine-grained pyrite and rarely small needle-like prisms of hornblende are sparingly scattered through the rock. In thin section (Spec. 506) under the microscope, the rock shows distinct banding due to the partial localization of sericite in narrow parallel bands. Quartz, the dominant mineral, occurs in small rounded grains associated with feldspar (albite?), which is usually clear and unstriated, though multiple twinning may be seen in places. Small cubes of pyrite and a very little chlorite make up the accessory minerals.

The rock exposed in the bottom of the shaft is a dark greenish-gray gneiss in which the banding is only imperfectly developed. In thin section (Spec. 503), the minerals identified in order of their abundance were hornblende, feldspar, quartz, biotite, chlorite, magnetite, and a little carbonate. The hornblende is light green in color.

and has rather low interference colors. The cleavage is good but the crystals are irregular in outline and contain occasional inclusions of the other minerals. Alteration to chlorite is frequently shown. Part of the feldspar is twinned after the albite law, but much of it is unstriated and difficult to distinguish from quartz, which it closely resembles in refraction and birefringence. The biotite is light brown in color and strongly pleochroic. Angular grains of magnetite are scattered through the slide and a little carbonate is present.

The small amount of carbonate contained in the gneiss just described, and its absence in the light-colored variety from the "H. V." shaft, is in marked contrast to its abundance in specimens from other parts of the mine. The relative scarcity of carbonate in these rocks may be due to greater depth below water level—75 or 80 feet—or possibly it is to be explained by distance from the vein—about 25 or 30 feet.

In the southwest end of the mine near the "12th of May" shaft the vein is 2 inches to 3 feet wide and averages about 14 inches. For some distance it splits up into two separate stringers which in places are slightly contorted. Slickensides were noted in a number of localities, but the vein is little affected by faulting. Radiating prisms of black tourmaline are of rare occurrence, being found occasionally in quartz from near the shaft. Most of the wall rock in this portion of the mine shows much decomposition, but in the floor of the drive 125 feet southwest of the "Sulphur" shaft there is a little fresh gneiss exposed on the foot-wall side of the vein. The rock (Spec. 118) is white to light greenish-gray in color where fresh, but along joint planes it is stained brown from the alteration of iron minerals, and in places the stain extends several inches from the fracture surface. Quartz and feldspar are the chief minerals with chlorite, hornblende, calcite, biotite, cyanite, and sericite present in smaller quantity. Cubes and irregular grains of pyrite are sparingly disseminated through the rock, and upon assaying an average sample it yielded 0.01 ounce of gold per ton.

Examination under the microscope shows that part of the quartz is present in small veinlets, probably as a result of mineralization by the vein-forming solutions. Part of the feldspar shows albite twinning, and is unquestionably acid plagioclase, but in most cases the twinning is absent and identification could not be made with certainty. There probably is some orthoclase present, but most of the unstriated feldspar is plagioclase. There are large areas in the thin section consisting of intercrystallized calcite and chlorite, possibly derived from hornblende, but some of the chlorite

was clearly formed from biotite. Areas of fine scaly sericite are present, some of which contain nuclei of unaltered mineral—probably cyanite.

The ore seems to occur in shoots that dip steeply toward the left as they descend along the vein, but this can not be verified until more development work has been done. One such ore shoot was found near the "Sulphur" shaft, and another between the "H. V." and the Chittenden shafts.

In the adits that were driven under the hill toward the "House" vein most of the country rock is soft and decomposed, but at several places where the floor of an adit approaches water level, fresh rock is encountered. Both the fresh exposures and the residual decay indicate that the rock is normally a hornblendic gneiss or schist, essentially the same as the dark variety of gneiss found in the underground workings on the "Sulphur" vein. In the immediate vicinity of the numerous veinlets and lenses which are exposed in the adits and have been worked to a limited extent for gold, the country rock exhibits certain important variations from the normal, which later will be described in detail.

The country rock, exposed near the portal of a prospecting tunnel that was started on the northwest side of the hill, is almost massive in the hand specimen (502), but shows a distinctly schistose structure under the microscope. Megascopically it is a dark greenish-gray, fine-grained rock, containing numerous idiomorphic garnets 1 to 2 mm. in diameter, and occasional rare grains of pyrite. The constituent minerals are amphibole, quartz, soda-lime feldspar, chlorite, magnetite, carbonate, a very little greenish-brown biotite, and quartz. In thin section most of the amphibole is green to bluish-green in color, and probably corresponds to common hornblende, but there are two other varieties present in small amounts. One is pleochroic in shades of light pink and dark greenish-gray, the interference colors being blues and greens of the second order, and is monoclinic in crystallization; the other is light yellowish-brown in color and orthorhombic in its crystallization. The latter mineral is present in much of the gneiss in this vicinity, but always in very small quantity. Hornblende is dominant over the other minerals and usually shows parallel orientation. Some of the feldspar (andesine) shows albite twinning, but much of it is unstriated and difficult to distinguish from quartz, which it resembles in refraction and birefringence. Much of the chlorite shows multiple twinning.

The veinlets and lenses vary from a fraction of an inch in thickness up to masses 2 feet wide and 25 feet or more in length. The shape of some

of the old openings suggests that even larger lenses may have been removed by previous mining operations. The veinlets are exposed in the adits on both sides of the hill, but are more plentiful in those that were driven from the west side. The larger lenses consist essentially of quartz, with pyrite and a little feldspar, the latter being chiefly concentrated near the walls though also occurring throughout the mass. In some of the smaller veinlets feldspar in places is dominant over quartz. Along fractures in the quartz-feldspar rock, much white mica is found in flakes 6 or 7 mm. in diameter with no regular orientation. While these crystals are quite large and may be primary muscovite, their localization along fractures indicates that they are probably secondary, derived from feldspar. Pyrite is very unequally distributed, occurring locally in masses several inches across, while elsewhere it is present in small quantity only. The larger masses seen were extensively altered to limonite.

Gold occurs in the native state both in the quartz and in pyrite, and there may also be a little telluride of gold present since tellurium has been detected in the ore. Mr. Knutzen states that the ore seems to be richest in gold near the walls of the lenses. The average value of $76\frac{3}{4}$ tons of ore obtained from these lenses and veinlets was \$4.10. Small grains of visible gold ranging up to 1 mm. and over in diameter are occasionally seen.

A piece of quartz, obtained from one of the lenses, contains embedded in it a grain of gold, averaging about 0.75 mm. in diameter, which is in contact with a minute speck of some soft cleavable mineral with metallic luster—probably tetradymite or sylvanite. Only 3 mm. distant from the gold, there is a cavity in the quartz, roughly cubical in shape, and about 1.5 mm. in diameter, which was filled with tetradymite, and in the latter a small crystal of pyrite was embedded. Part of the tetradymite was removed and tested for identification. It is tin-white in color, has a high metallic luster, perfect basal cleavage with flexible laminæ, and is quite soft, readily marking paper. Heated before the blowpipe it fuses easily and gives an orange-yellow sublimate. Upon gently heating with sulphuric acid in a test tube the acid assumes the beautiful reddish-violet color distinctive of tellurium. The same specimen of quartz contains a little kaolinized feldspar and some dark brown limonite derived from pyrite.

A thin section (Spec. 498) from one of the quartz-feldspar veinlets was examined under the microscope. The quartz individuals range up to 3 mm. in diameter, contain numerous irregular gas- and fluid-filled cavities, usually arranged in long rows, and show slight wavy extinction, but no granulation or other evidence of crushing. The feldspars range up to

1 cm. or more in diameter, and are easily distinguished from quartz because of a slight cloudiness due to partial alteration. Multiple twinning after the albite law is sometimes though not always present. The average index of refraction is a little less than that of quartz, and this together with the extinction angle indicates a composition of approximately Ab_2An_1 (oligoclase-andesine).^a A little sericite occurs in places, usually in clusters of curved and radiating scales. The only other minerals noted in the slide were a few grains of ilmenite and its alteration product leucoxene.

The larger lenses appear to be parallel to the strike and dip of the country rock, but many of the veinlets cut directly across. In places, as shown in fig. 11, small irregular veinlets and lenses run in every conceivable direction. Where stringers of quartz and feldspar cut across the cleavage of the gneiss, smaller veinlets branch off at short intervals and run parallel to the schistosity, giving rise to a banded rock which is very striking in appearance.

Specimens of this rock consist of alternating bands of light and dark minerals, ranging up to 1.5 cm. in width, which widen here and narrow there, and frequently pinch out entirely. Some of the light-colored bands are composed essentially of quartz and feldspar, while others consist largely of sericite; and the dark-colored bands are composed chiefly of dark green hornblende, with sulphides of iron and magnetite abundant in places. The quartz-feldspar bands resemble veinlets, and when the rock is fresh it is difficult to distinguish between the two component minerals, as they are both white. The rock breaks most readily along the sericite bands and there presents a light gray surface on which long, narrow, glistening streaks of sericite are plentifully sprinkled. These streaks of sericite average about 2 mm. in width and range up to 2 or 3 cm. in length. On some of the specimens a little light blue cyanite can be distinguished, and the sericite streaks are probably due to the alteration of that mineral. The dark-colored bands when narrow consist of dark green hornblende with a sprinkling of magnetite, but some of the wider bands have a narrow border of coarsely crystalline hornblende 2 to 3 mm. wide along their contacts with the quartz-feldspar veinlets, while their central portions are filled with a fine-grained mixture of carbonate, hornblende, pyrrhotite, pyrite, and magnetite.

^aA specimen of this feldspar was submitted to Dr. E. S. Larsen, Jr., for accurate determination of the maximum and minimum indices of refraction by the immersion method. His report is as follows: "Oligoclase to andesine. Dominantly andesine or oligoclase-andesine.

$$\alpha = 1.539 \pm 0.003 \text{ to } 1.544 \pm 0.003$$

$$\gamma = 1.546 \pm 0.003 \text{ to } 1.553 \pm 0.003$$

Extinction on the rhombic section $12\frac{1}{2}^\circ$ andesine."



Fig. 11.—Sketch showing distribution of vein quartz, Young American mine.

The size of the hornblende crystals seems to vary somewhat with the width of the veinlets with which they are in contact, and along some of the larger veinlets they are 1 cm. in diameter, while prismatic crystals of tremolite, which is also present, measure as much as 2

cm. in length. Tremolite is frequently abundant near the quartz-feldspar stringers, sometimes being roughly segregated into bands, but does not appear to be an important constituent in the normal country rock. Occasionally elongated grains of a light brown mineral may be seen, which under the microscope were identified as orthorhombic amphibole.

Microscopic examination of thin sections (Specs. 499, 500, and 501) shows that the principal minerals have undergone extensive alteration, and it is not always possible to say just how much of this was due to the injection of the quartz-feldspar veins and how much is due to weathering. The hornblende is pleochroic in shades of light green, blue, and brown, and has low interference colors. The tremolite is colorless and shows rather high interference colors. In both varieties of amphibole, but especially in the hornblende, cleavage is well developed; both are ragged in outline and frequently show micropoikilitic texture; and each contains occasional inclusions of the other. Both show extensive alteration to carbonates, and chlorite, probably derived from hornblende, is also present. The carbonates in places contain small irregular fragments of amphibole, which, on rotating the stage, extinguish together, indicating that they belong to a single crystal individual. In addition to the monoclinic amphiboles there is a small amount of light yellowish-brown orthorhombic amphibole present. It occurs in elongated crystals with poor cleavage and ragged outlines which only rarely show straight prismatic boundaries. Extinction is parallel to the elongation and the refraction and birefringence are moderate. Quartz occurs in clear irregular anhedral which sometimes contain numerous liquid and gas inclusions. The feldspars usually show fine albite twinning, and some are also twinned according to the pericline law, while others show no visible striations. The index of refraction averages about the same or slightly higher than quartz, indicating that they are chiefly andesine or oligoclase-andesine. Orthoclase is rare if present, and has probably been entirely altered to sericite. Some of the feldspars show alteration to calcite. Sericite is rare except in light-colored bands which are composed almost exclusively of this mineral. It occurs in long flakes or scales which usually show good cleavage, and is secondary after both cyanite and feldspar. In places a little unaltered cyanite can be distinguished in the slides, but it has almost entirely gone over to sericite. The iron ores—pyrrhotite, pyrite, and magnetite—are plentifully distributed throughout the slide, but are more abundant in the areas of dark-colored minerals. The magnetite is frequently idiomorphic, and the sulphides in places surround the magnetite. A little biotite, light

brown to greenish-brown in color, is occasionally present in small disseminated flakes.

In the partly decomposed gneiss exposed by the adits, there are numerous slickensided surfaces stained black with manganese, probably in the form of wad. Some of these surfaces are very large, covering an area of at least several square yards. As a rule they conform in strike and dip to the schistosity of the formation, and they are common along the walls of the quartz veins. Similar slickensided surfaces occur in the workings on the "Sulphur" vein, but they were not found in the lower openings where the rock is unaltered by weathering. Because of their localization in the weathered material it is believed that these slickensides are due to changes in volume resulting from decomposition.

The Belzoro Mine.

Location.—The Belzoro mine, consisting of about 374 acres, is located 6 miles northeast of Columbia and three-quarters of a mile north of Lantana. The veins on this tract evidently belong to the same system as the "House" vein on the property of the Young American mine (see pp. 134-139), which adjoins the Belzoro on the northeast.

History.—Mr. Hamilton states that "the antiquity of the Belzoro mine is evident from the fact that crucibles, made by the Indians, or perhaps some remoter and unknown tribes, have been found on it, bearing a rude resemblance to an acorn cup, and manifestly devoted to the use of melting the precious metals,"^a but in this belief he is probably mistaken. No articles of Indian manufacture made from gold have been found in Virginia, and students of the North American Indian are generally agreed that he was ignorant of the art of melting metals. The so-called crucibles were probably used for some other purpose and doubtless were brought from the Indian soapstone quarries 3 miles northeast of this property, which are described on pages 170-171.

Gold was discovered on the Belzoro tract by surface washing in 1832, at which time the property belonged to Mr. William Southworth. The placer gravels are said to have been very productive, \$30,000 having been recovered from a limited section known as "Dry Gulch."^b Bed rock was 1 to 6 feet below the surface and many nuggets weighing from 4 to 7 pennyweights were found.^c The work of washing gold from the gravels con-

^aHamilton, J. R., *The Natural Wealth of Virginia*, *Harper's Magazine*, 1865, vol. xxxii, pp. 32-42.

^bSnell, P. A., From a report on the Belzora mine.

^cHamilton, J. R., *Op. cit.*

tinued with varying success up to 1849, when the property was sold to Mr. Geo. Fisher.

Several shafts were sunk to depths 30 to 60 feet and many surface cuts and pits were opened. A 10-stamp mill was built to treat the ores which are said to have yielded as high as \$300.00 per day, but all mining operations were interrupted by the Civil War. After the close of the war a little work was done from time to time, but the mine has remained idle since the mill burned some years ago.

Descriptive geology.—There are no outcrops on the property and very little float rock aside from vein quartz can be found. The old workings have caved and are now inaccessible, but information obtained elsewhere in the vicinity confirms the data collected on the property and indicates that the country rock consists of a series of quartzose gneisses and schists varying somewhat in composition. A number of large pieces of float were found near the branch where it is crossed by the road a short distance northeast of the house. This rock is a light gray, slightly banded gneiss composed for the most part of quartz, white mica and feldspar, with a little dark mica and magnetite. A detailed petrographic description is given on page 39. While the rock was not found in place at this point it does outcrop beyond the limits of the property in both directions along the strike and is probably the dominant rock type in this vicinity. The ferruginous quartzite found on the Webb place (see pp. 19-20) also continues on this property. The veins are said to be enclosed in light-colored quartz-sericite schists (the talcose slate described by some of the early writers).

According to P. A. Snell there are two well-defined veins on the property 300 yards apart, one averaging from 2 to 3 feet in width, and the other from 3 to 4 feet, while the course of both is northeast and southwest and the dip 45° toward the southeast, approximately parallel to the strike of the country rock. The two principal veins are paralleled by a large number of flat lens-like ore-bodies varying from 1 to 6 inches in width which are not continuous for any great distance, but pinch out and start in again a little to one side or farther along the strike.^a

The ore is described as quartz carrying iron pyrite which is largely oxidized near the surface, and on either side of the veins there is said to be a narrow selvage of clay and grit (probably kaolin from the decomposition of feldspar), which is quite rich in gold, the latter showing plainly

^aSnell, P. A., Op. cit.

Credner, H., Report of Explorations on the Gold Fields of Virginia and North Carolina, Amer. Jour. Mng., 1868, vol. vi, p. 393.

on panning a little of the material. This description indicates a type of ore-deposit similar to the lenses that parallel the "House" vein on the property of the Young American mine described in detail on pages 134-139.

These small lenses were worked entirely by open cuts and the ore obtained was washed through sluices or rockers to separate the free gold in the soft material (kaolin), which varied in value from \$2 to \$20 per ton. After the fine material was washed away the balance consisting of coarse quartz was put through the mill to recover the gold that it contained.

Production.—Mr. Snell believes that about 2,000 to 2,500 tons of ore have been milled, this being derived mostly from the two principal veins but partly from the open cuts on the small lenticular ore-bodies. The property is estimated to have produced from placer gravels and from veins a total of not less than \$100,000.^a

The Collins Mine.

The Collins mine is situated on the east side of the Belzoro property 1 mile northeast of Lantana. It was probably the first mine worked for gold in this district if not in Virginia. Gold was first found in the branch crossing the property, and while the exact date of the discovery is not known, it must have been prior to 1830. The Fishers made preparations to work the gravels, building dams across the branch and installing rockers, but before operations were actually under way they turned the property over to Steven Collins and began work on the Busby branch instead. Mr. Collins washed the branch gravels successfully for several years, and later gold-bearing gravels were found 30 or 40 feet above the branch on the north side. Sluice ways were cut from the bottom of the hill and the gravel worked by hydraulic mining. Little if any vein-mining was ever conducted on the property.

In addition to the mines described above gold has been reported on a number of properties in the vicinity of Lantana, and a little prospecting has been done at several places, chiefly for placer gold. On a property lying south of the Belzoro mine and formerly known as the Marks mine, surface washing was commenced in 1830 by Woodfork and continued for some time by various owners. Other placer mines which have been operated at various times in this neighborhood were known as the Eades, Big Bird, and Laury mines.

The Morgan Mine.

The Morgan mine is located just west of the property belonging to the Young American mine. The placer gravels on this place were early

^aSnell, P. A., Op. cit.

worked for gold and later some vein mining was done. According to Credner the main vein is 4 feet wide and a smaller parallel vein in the hanging wall was also worked. Before the war, ore was hauled to the Belzoro mill and is said to have yielded 70 pennyweights of gold per day, or about \$3,000 in eight months.^a Later a 10-stamp mill was built but the size of the tailings pile indicates that little ore was milled. At present nothing remains of the mill and the old shafts and pits are completely caved.

The Grannison Mine.

The Grannison mine is situated on the west side of Camp Branch, a mile northwest of Lantana and a mile south of Caledonia. The placer gravels were extensively and successfully worked during the period that preceded the Civil War, and 3 quartz veins were opened up. One of these was worked to some extent by open pits and a shaft 42 feet deep. After the war the veins were reopened and a 10-stamp mill built near the branch, but at present the mill is in ruins and all of the old workings caved. Most of the work seems to have been done a short distance northeast of the mill where there is a series of old shafts and pits extending for about 150 yards in a direction N. 45° E. There are several pits located a quarter of a mile north, said to have been opened on a smaller vein which was very rich.

Atmore, Kent, and Other Properties.

On the Atmore and Kent properties, lying southwest of the Grannison mine, several veins have been explored and a little mining done, but all of the work has been of a superficial nature. Small veins have been prospected on a number of other places in this vicinity, but aside from placer washing practically no mining has been attempted. Nearly all the gravels along Camp Branch and some of the smaller branches that enter it have been washed for gold.

The Bertha and Edith Mine.

Location.—The Bertha and Edith mine is situated on the east side of Big Byrd Creek in Goochland County, 3 miles northeast of Columbia.

History.—The placer gravels along the branches were first worked prior to the Civil War, and the Maple and Camp branches which flow through the property are said to have yielded much gold. In 1877, the Bertha and Edith Gold Mining Company bought the mineral rights and began

^aCredner, H., Report of Explorations on the Gold Fields of Virginia and North Carolina, Amer. Jour. Mng., 1869, vol. vii, pp. 26-27.

development work on the quartz veins. A little later a Fraser and Chalmers 20-stamp mill was erected to crush the ore and recover the gold. In 1882, the Tagus Mining and Milling Company, which was operating the Gilmer (Young American) mine, 4 miles northeast, obtained a lease and option on the property and began work. During this lease some hydraulic mining was carried on, water being furnished under pressure by a large pump and the gravel washed through sluice boxes. Several veins were prospected by surface openings but most of the underground development was limited to the "Oak Hill" and "Maple Branch" veins. The "Oak Hill" vein was explored by an adit 400 feet long, which drained the hill 75 feet below the summit and was connected with an upper level on which there were 300 feet of drives and cross-cuts.^a The "Maple Branch" vein was explored by a tunnel, but work had to be stopped on account of bad ground.

In 1897, the Rivanna Gold Mining Company reopened the "Oak Hill" vein and built a cyanide plant to treat the tailings from the stamp mill. Milling had scarcely begun before the whole plant was destroyed by fire in 1898, and since that date no work has been carried on. While the "Oak Hill" vein was being reopened the company prospected the placer gravels in the flat near the mouth of Camp Branch and started to work the deposits, the method being to first remove the overburden with scrapers and then wash the gravel in rockers, but this was discontinued when the mill burned. At the present time the shafts are partly caved and all the underground workings are inaccessible.

Description of veins and country rock.—The country rock in which the veins are located consists chiefly of schists and gneisses of sedimentary origin, and their contact with hornblende border facies of the granite is only about half a mile southeast of the "Oak Hill" vein. The dominant rock in the sedimentary series is a medium-grained gneiss composed essentially of quartz, sericite, and feldspar in the order named, with a little biotite and a few grains of magnetite. This is the only rock outcropping on the property excepting along the bluffs that border Big Byrd Creek where quartz-sericite schists and hornblende schists occur in places.

The "Oak Hill" vein varies up to 6 feet in width and is said to have averaged about 3 feet. Ore found on the dump consists of ordinary vein quartz containing considerable fine-grained pyrite, which is partly oxidized to limonite, and on crushing and panning it shows fine grains and scales of free gold. Some of the pieces show a little white mica and kaolin un-

^aHotchkiss, Jed., Virginia Minerals for the New Orleans Exposition, The Virginias, 1884, vol. v, p. 166.

doubtedly derived from feldspar. A little magnetite is occasionally present. The ore from this vein is said to have averaged a little over \$5.00 per ton. The "Maple Branch" vein has a northeast-southwest strike and is said to be much narrower but richer in gold than the "Oak Hill" vein. Miners, who worked on the property when the openings were made, state that this vein carried a large amount of white kaolin. The "House" vein, situated about a quarter of a mile northwest of the other two, has been worked to a limited extent, but nothing definite could be learned concerning it. Float rock picked up on the surface assayed as much as \$32.75 per ton. There are some placer gravels remaining on the property that have never been worked (see pages 239-240).

The Pryor Tract.

The Pryor property is located $1\frac{1}{2}$ miles southeast of Tabscott and lies south of the Busby mine. The placer gravels along Busby Branch, which crosses this property, were worked soon after the first discovery of gold in the district. Recently several small shafts have been sunk on the property in the hope of locating the "Waller" vein, but, so far as is known, nothing of value was found.

The Moss Mine.

Location.—The Moss mine is located on the south side of the Columbia-Tabscott road, about 8 miles northeast of Columbia and $1\frac{1}{2}$ miles southwest of Tabscott.

History.—The Moss vein, on which most of the work has been done, is said to have been discovered in 1835 by John Moss.^a Prof. Silliman,^b reporting on the property in 1836, found the mine developed by two incline shafts sunk on the vein; one measuring 31 feet along the slant and having a vertical depth of 25 feet, while the other was 50 feet deep, though the lower 20 feet was inaccessible at the time of his visit. The two shafts were connected by an adit 70 feet in length and the vein was exposed throughout the length of these workings. Measurements taken at intervals along the vein ranged from 16 to 30 inches in width and averaged about 24 inches. The inclination, about 45° toward the southeast, and the strike, about north by east and south by west, were conformable with the stratification of the inclosing slaty rocks. A sample was taken by knocking off pieces of ore at intervals of 12 feet along the vein and this, after being

^aNitze, H. B. C., and Wilkins, H. A. J., *Gold Mining in North Carolina and Adjacent South Appalachian Regions*, Bull. 10. N. C. Geol. Survey, 1897, p. 75.

^bSilliman, B., *Remarks on Some of the Gold Mines and on Parts of the Gold Region of Virginia*, Amer. Jour. Sci., 1837, vol. xxxii, pp. 98-130.

broken down and subdivided to give a final sample of 9 pounds, was washed and amalgamated; the button of gold recovered in this manner weighed 11 grains, giving the ore a value of about \$105 per ton. In another trial Prof. Silliman obtained 6 grains of gold from 3½ pounds of powdered rock in which no gold was visible, and in a third experiment two pounds of ore yielded 5 grains of gold.

Credner states that the Moss mine was worked from 1836 to 1838 by a company (The Richmond Mining Co.) whose shares rose in a year's time from \$5 to \$300, but fell as quickly to nothing.^a

The mine was reopened in 1891 and tests made on the ore with a 3-stamp prospecting mill,^b and during 1904 the property was operated under lease by the Telluric Gold Mining Company.^c At this time the mine was developed by 2 main shafts, known as No. 1 and No. 2. The No. 1 shaft was sunk on an incline to a depth of 118 feet, and levels run east and west a total distance of 285 feet in ore milling \$15 per ton. In the west level a small shoot was encountered which averaged \$150 per ton in gold, and 40 ounces in silver. The No. 2 shaft was carried to a depth of 130 feet and levels driven 60 feet east and west along the vein, the ore developed milling \$14.40 per ton. A 3-stamp battery was added, giving the mill a total of 6 stamps. Regular assays of tailings indicated an average of \$2.00 per ton.

Descriptive geology.—The vein is said to consist of laminated quartz lying in more or less lenticular masses between walls of micaceous slate. Pieces of the ore examined by the writer are in the form of thin plates 0.5 to 1 inch thick, and broken along joint planes spaced 5 to 9 inches apart. Coarse gold, in grains about 0.5 mm. in diameter, is sprinkled along the surfaces of the laminæ, a little pyrite mostly altered to limonite is present, while flakes of white mica and considerable kaolin, probably derived from feldspar, were also noted. Black tourmaline is said to have been common in some of the ore and prisms of this mineral were found in a number of pieces of float on the surface.

Specimens found on the shaft dumps indicate that the wall rock is a dark gray schist with slaty cleavage, composed for the most part of fine-grained quartz and biotite, varying somewhat in their relative proportions but with the quartz always largely in excess. A few small black needle-like prisms

^aCredner, H., Report of Explorations on the Gold Fields of Virginia and North Carolina, Amer. Jour. Mng., 1869, vol. vii, p. 27.

^bEng. and Mng. Jour., 1901, vol. lii, p. 108.

^cFroehling and Robertson, A Hand-Book on the Minerals and Mineral Resources of Virginia, 1904, pp. 51-52.

of tourmaline or hornblende are also present. The soft running ground which is reported to have given much trouble in shaft sinking, was probably due to disintegrated schist of this character saturated with water.

Pieces of hornblende schist were also found on one of the dumps. This is a greenish-gray, medium-grained rock composed of dark green hornblende in crystals ranging up to 2 or 3 mm. in diameter, fine-grained, white quartz and feldspar, and numerous pink garnets, usually less than 1 mm. in diameter. In thin section under the microscope the hornblende is light green in color, very ragged in outline, and micropoikilitic from numerous inclusions of quartz and feldspar. Quartz, the second mineral in relative abundance, frequently contains inclusions of broken zircons, and gas- and liquid-filled cavities. The feldspar is plagioclase, probably andesine, and in places shows albite twinning though this is usually absent. The large, light pink garnets which are plentiful in the slide are often ragged in outline and contain many included quartz grains. Chlorite, partly derived from garnet but mostly from the hornblende, is present in light green flakes. A very little biotite, scattered grains of magnetite, and some pyrite, partly altered to limonite, make up the minor accessories. In the absence of a chemical analysis or data bearing on the structural relations of this rock it is impossible to state whether it is igneous or sedimentary in origin, but the writer is inclined to the latter alternative.

An old shaft, partly caved, which is located close to the county road is said to have been sunk to cut the Hodges vein. Partly decomposed garnetiferous mica schist is exposed on the dump.

The Busby Mine.

The Busby mine lies $8\frac{1}{2}$ miles northeast of Columbia and 1 mile southwest of Tabscott, joining with both the Moss and Bowles properties. It was one of the first gold mines in the State to be worked, the placer gravels on Busby Branch having been washed by the Fishers as early as 1829 or 1830. In working up the branch, the Busby vein was discovered, and then a small wooden stamp mill run by horse-power was put up by the Fishers and D. W. K. Bowles.

In 1836, when Prof. Silliman^a visited the district to report on the Moss and Busby mines, they were being developed by the Richmond Mining Company. A shaft had been sunk to a depth of 57 feet with the

^aSilliman, B., Remarks on Some of the Gold Mines, and on Parts of the Gold Region of Virginia, founded on personal observations made in the months of August and September, 1836, *Amer. Jour. Sci.*, 1837, vol. xxxii, pp. 98-130.

expectation of striking the vein at 70 feet, the vein having first been proved by 4 prospecting pits 20 to 26 feet in depth. These openings showed the vein to be from 12 to 30 inches wide, averaging 15 to 18 inches. The vein quartz, as described by Prof. Silliman, has a coarsely granular texture with a strong resemblance to coarse lump sugar, much of it being white and apparently free from all foreign matter other than the inherent gold. A 6-pound sample picked at random from a large pile was crushed, washed, and the gold amalgamated with mercury; upon retorting it yielded 6 grains of gold worth $4\frac{1}{12}$ cents per grain. This is equivalent to over \$81 per ton. A picked sample containing small points of visible metallic gold, when treated in the same way, yielded 6 grains of gold from 2 pounds of ore, or about \$250 per ton.

Notwithstanding the reported value of the ore, comparatively little mining seems to have been carried out on the property, and when it was visited by Credner in 1865 the mill was in ruins.^a He states that the continuation of the Moss vein was exposed by 4 shafts the first and last of which were one mile apart.

When visited by the writer in 1910 the shafts had caved so that few observations could be made. Several old pits are located about 50 yards north of the Columbia-Tabscott road and in line of strike with the Tellurium vein system. On the dump of one of these openings pieces of quartzite were found identical in appearance with the material from the "Big Sandstone" vein, but whether it has been mineralized at this point or not, could not be determined. About 100 yards south of the road a small pit had been sunk, apparently on a ferruginous quartzite similar to that known as the "Hodges" vein at the Scotia mine.

The Payne Tract.

The Payne tract is located on the south side of the county road half a mile southeast of Tabscott. It adjoins the Busby mine and was formerly a part of that property. There are a number of old surface cuts and caved shafts which extend in a line running about N. 58° E. A large pile of mill tailings a short distance below the openings indicates the site of the old mill of which no other trace remains. The mill that Credner found in ruins when he visited the Busby mine was probably located at this point. In 1911 an attempt was being made to reopen one of the old shafts.

^aCredner, H., Report of Explorations on the Gold Fields of Virginia and North Carolina, Amer. Jour. of Mng., 1869, vol. vii, p. 27.

The Waller Mine.

Location.—The Waller mine is situated in Goochland County half a mile southeast of Tabscott and about 10 miles northeast of Columbia, the nearest railroad station.

History.—The Waller mine was discovered in 1831, and during that year Cole and Woolfork carried on surface washings for several months. Veins were discovered by Moss in 1832, and a vein 6 feet thick is said to have been opened by the Fishers and worked until the land was purchased by Wm. K. Smith. Later it was sold to Richards, of New York, who worked the mine 12 months and then sold it to an English company for a large sum. After two years, during which it is said to have been badly managed, the property was divided and sold in two parts. Since that time only the western part of the old estate has been known as the Waller mine. In 1865, Turner, Hughes & Co. sank a shaft and did some development work, but since that date nothing has been done, aside from 30 days' work in 1876, until the present company began operations in 1910.^a During the latter year a shaft was sunk to a depth of 72 feet and two cross-cuts driven northwest at depths of 45 and 60 feet, respectively. A small vein, said to be the Waller vein, was encountered in the 60-foot cross-cut, but the drive which was started southeast along the vein soon ran into old workings. Another shaft was started in 1911 to strike the vein at greater depth, but when the property was visited in the summer of that year the vein had not been reached. A small mill is said to have been operated on the property in the early days but no trace of it remains to-day. Before the property was divided, veins belonging to the Tellurium system which crossed the northwestern portion of the property were also developed to some extent.

Descriptive geology.—The mine is situated in an area of schists and quartzites not far from their contact with the hornblende border facies of the granite, which is found outcropping a short distance southwest of the property. Because of lack of exposures it is not possible to accurately locate the contact at this point, but many pieces of hornblende schist were found on the surface within less than 200 yards southwest of the vein. About a quarter of a mile northeast of the vein a small pit was sunk in prospecting for iron. The material encountered seems to have been a ferruginous quartzite similar to that found elsewhere in the district. About half a mile northwest of the mine occurs the same series of quartzites and schists found at the Tellurium mine.

^aMost of the facts stated above were taken from "The Natural Wealth of Virginia," by J. R. Hamilton, *Harper's Magazine*, 1865, vol. xxxii, pp. 32-42.

The strike of the Waller vein at the surface, as indicated by the old open cuts and caved stopes which extend for about 300 yards along the outcrop, is N. 58° E. When the mine was examined by the writer, the vein was exposed for a distance of only 25 feet along the strike at a depth of 60 feet below the surface. At this point the dip was about 40° toward the southeast and the strike N. 60° E. The width of the vein where it could be measured ranged from 4 inches down to less than an inch, and was composed for the most part of quartz, feldspar, more or less kaolinized, and a little limonite resulting from the alteration of pyrite. The relative proportions of these constituents varied greatly; where widest the vein consisted almost entirely of white vitreous quartz, but in most places feldspar was abundant, and in some of the narrower portions was dominant. The limonite was commonly mixed with kaolin and quartz to give an earthy, yellowish-brown material, which often contained much coarse gold.

The textural relations of the quartz and feldspar are similar to those of a typical pegmatite and in places there is a suggestion of graphic intergrowths. The feldspar individuals range up to 1 cm. or more in diameter, and in the wider portions of the vein are more or less concentrated near the walls. The gold when visible occurs in irregular grains and rough wire-like masses, some of which measures 3 mm. in length, and is usually associated with decomposed earthy material heavily stained with limonite. Specks of gold may occasionally be seen in feldspar and clear, unstained quartz, and more rarely in the wall rock close to the vein.

Microscopic examination of the vein rock in thin section (Spec. 217) shows no accessory minerals other than a little sericite derived from the feldspars. The quartz is nearly free from optical distortion and contains numerous gas- and liquid-filled cavities. These cavities occur partly in irregular branching and interlaced forms, and partly in smaller spherical and elliptical shapes which are usually grouped in rows and planes. In places the inclusions are so small and plentiful as to give the quartz a clouded appearance even under a magnification of 200 diameters. The feldspars are extensively kaolinized and show some alteration to sericite, but apparently consist entirely of acid plagioclase (albite-oligoclase to oligoclase).^a Twinning after the albite law is common, though much of

^aDr. E. S. Larsen, Jr., using the immersion method, determined these feldspars to be albite-oligoclase to oligoclase and states that the fresher crystals appear to be oligoclase. The indices of refraction as determined by him are:

$$\begin{aligned}\gamma &= 1.535 \pm 0.003 \text{ to } 1.538 \pm 0.003 \\ \gamma &= 1.543 \pm 0.003 \text{ to } 1.547 \pm 0.003\end{aligned}$$

the feldspar is unstriated. A photomicrograph of some of the striated feldspar is shown in Pl. VIII, fig. 2. The narrow veinlet crossing the feldspar is composed of quartz.

The wall rock is fine-grained and badly decomposed, so that it is very difficult to obtain specimens fresh enough for identification. The rock exposed on the hanging wall side of the vein is dark blue in color and consists essentially of quartz and magnetite in grains that are too small for sight determination. For a distance of 3 feet or more from the vein there are numerous veinlets composed of quartz and feldspar, which range from an inch or more in thickness down to threads and lenses microscopic in size, and which are approximately parallel to the main vein. Limonite and iron-stained cavities due to the oxidation of pyrite occur in places, and there is probably some gold, for these veinlets appear to be essentially the same as the vein in which gold was identified. Small flakes of biotite usually occur along the contact between the veinlets and the country rock, and the mica is plentiful along both walls of the principal vein. The rock on the foot-wall side was not as well exposed. Where it could be examined it was much weathered, but appeared to consist of biotite, kaolinized feldspar, and quartz. Pieces of rock from the hanging wall sometimes contain small, light brown crystals, often radiating, which resemble sillimanite, but are too small and too much decomposed for positive identification.

A thin section (Spec. 219) of the hanging wall rock was also examined under the microscope. It is schistose in structure and consists of a fine-grained ground-mass of quartz, magnetite, and a little feldspar, in which there are numerous small irregular lenses and veinlets composed of coarser grained quartz and feldspar. The quartz grains in the ground-mass show wavy extinction, the magnetite is present in idiomorphic grains, and the feldspar, which seems to be chiefly acid plagioclase, is more or less kaolinized. The quartz in the lenses shows no optical distortion, and frequently contains numerous small fluid-filled cavities. Many of these cavities contain rapidly vibrating bubbles. A little zircon and titanite are also present as inclusions in the quartz. Feldspar is not very plentiful, and is chiefly concentrated along the border portions and at points where the lenses pinch out. Most of the feldspar crystals show Carlsbad twinning and are probably orthoclase, but a little acid plagioclase is also present.

On the surface near one of the old openings pieces of vein rock were found which consist of intercrystallized quartz and calcite. The calcite is coarsely crystalline, has curved cleavage surfaces, and contains much iron and a little magnesium. Dark green hornblende partly altered to chlorite and a little pyrrhotite are also present in the calcite and along its margins. Other pieces of rock on the old dump have a banded structure and are composed of alternating layers in which the dominant minerals are, respectively, coarsely crystalline, dark green hornblende and white finer-grained calcite. Lenses of quartz occur in places and there is a little pyrrhotite and some pyrite present.

The Fleming Mine.

Location.—The Fleming mine is situated in Goochland County about a mile northeast of Tabscott and on the southeast side of the county road.

History and description.—The placer gravels on this property are said to have been washed during the early days of gold mining in the district. Underground work was started by General Cook in 1846 and a 6-stamp mill operated by him is said to have yielded on occasions as much as \$200 per day. This success, however, was short-lived as the vein was soon lost. At this time two shafts were sunk to depths of 60 and 35 feet, respectively. During its early history the property was known as Hodge's mine, but in 1848 it was sold to the L'Aigle d'Or Company of New York.^a Little development work was attempted until after the Civil War, when the mine was reopened by several small shafts, and since that time it has been known as the Fleming mine.

When the property was visited in 1910 all of the openings were inaccessible; a series of old pits and shafts was seen extending in a direction N. 60° E. for about 150 yards, and in one of the shafts decomposed schists were exposed having a strike of N. 61° E. and a dip of 45° toward the southeast. A few pieces of vein quartz were found on the dump, but they showed little evidence of mineralization.

Shannon Hill.

Shannon Hill is the most northeasterly point within the area where gold has been found. Some prospecting was carried on here years ago,

^aCredner, H., Report of Explorations on the Gold Fields of Virginia and North Carolina, Amer. Jour. Mng., 1869, vol. vii, p. 26.

but nothing further seems to have been done. Credner examined the property in 1865 and states that a lode, 1 to 3 feet wide and paralleled by two smaller veins, was exposed by surface pits. The strike is given as N. N. E. and the dip 40° to the east. The veins are said to consist of white translucent tabular quartz with a great deal of earthy oxide of iron and some gold. Garnetiferous mica schist outcrops in the road at Shannon Hill, having a strike of N. 45° E. and a dip of about 45° southeast. While considerably decomposed it is apparently similar to the wall rock at the Tellurium mine and probably represents the same formation. Placer gravels were washed on this property before the Civil War and considerable gold is said to have been recovered.

The Benton Mine.

Location.—The Benton mine is located in Goochland County about three-quarters of a mile northeast of Tabscott and on the northwest side of the county road.

Description.—This property was explored by a shaft, now inaccessible, and the size of the dump indicates that it reached a considerable depth. The country rock found on the dump is a garnetiferous schist similar to the wall rock at the Tellurium mine, and pieces of vein quartz were seen that contained a little kaolinized feldspar and some white mica. The property is in direct line of strike with the Tellurium system of veins, and this fact together with the material found on the dump indicates that the vein is similar in its general characteristics to those described under that mine. There is a number of old pits and caved shafts between this point and Tabscott, which were probably sunk in prospecting the same vein or others belonging to this system, but the openings are so old that the material on the dumps has completely disintegrated, and therefore no definite information could be obtained concerning the exposures. A few pieces of massive diorite, evidently derived from some dike, were found on the surface. The rock is described in detail on page 85.

The Tellurium Mine.

Location.—The Tellurium mine, located $7\frac{1}{2}$ miles northeast of Columbia and $2\frac{1}{2}$ miles southwest of Tabscott, lies partly in Fluvanna and partly in Goochland counties.

History and description.—It was one of the first properties in Virginia on which vein mining for gold was attempted, and its history differs from that of most mines in this section in that the veins were discovered and worked before the placer gravels. The first discovery on the place was made in 1832 by G. W. Fisher while hunting, and in 1834 the property was leased from its owner, Mr. Hughes, by Geo. Fisher, his two sons, G. W. and J. A. Fisher, and Judge D. W. K. Bowles.

At first the ore was raised and crushed by hand, and the gold separated from its gangue by washing in a box. The crushing was carried on in wooden mortars lined with iron, the heavy pestles being attached to sweeps which were likewise operated by hand. Later an arrastra driven by horse-power was installed, and finally a small stamp mill was built on the branch about one mile below the mine. This was probably the first stamp mill, or "pounding mill" as they were originally called, to be erected in this country, and it is supposed that the innovation was derived from Europe. According to Nitze and Wilkins,^a a 6-stamp mill was in operation at the Tellurium mine as early as 1836. The ore was crushed on an iron die plate by 50-pound wooden stamps with iron shoes; the stamp stems were square and did not revolve as in later mills, for the cams worked in slots cut into the stems.

The mine was in continuous and profitable operation for 14 years under the Fisher-Bowles lease, and during that period the work was confined to the "Little" and "Middle" veins which are said to have been the richest, but very little authentic information regarding the production or the value and character of the ore is obtainable at this date. The "Little" vein is said to have averaged less than a foot in width and the deepest workings were only 65 feet, though as a rule the vein pinched out before this depth was reached. According to G. W. Fisher 100 pounds by weight of the richest ore ever obtained from this vein, on crushing and washing, yielded 210 pennyweight of gold.^b The "Middle" vein is said to have averaged 1½ to 2 feet in width but the ore was not so rich as the "Little" vein.

Dr. Gray, in a letter to Dr. Thomas Pollard, gives the average value of the ore obtained from the two veins during this 14-year period as \$100 per ton.^c Prof. B. Silliman visited "Fisher's or Hughes' mine," as the property

^aNitze, H. B. C., and Wilkins, H. A. J., *Gold Mining in North Carolina and Adjacent South Appalachian Regions*, Bull. 10, N. C. Geol. Survey, 1897, p. 35.

^bStatement made to the writer by R. H. Fisher, nephew of G. W. Fisher.

^cHotchkiss, Jed., *The Tellurium Mine and Virginia Gold Mining, The Virginias*, 1881, vol. ii, p. 85.

Pollard, Thomas, *The Gold Belt of Virginia in "Gold, Its Occurrence and Extraction,"* by A. G. Locke, New York, 1882, pp. 182-190.

was variously called at that time, in 1837, and quotes Mr. Fisher as saying, that the average value of the ore was \$3.15 for every 100 pounds, while the cost did not exceed 30 to 35 cents per hundred pounds.^a According to local report, the lessees paid a royalty of 10 per cent. of the gold recovered, and during the period of the lease Mr. Hughes received as his share \$13,000 or \$15,000, the accounts differing as to the exact amount, making a total production of \$130,000 or \$150,000.

In 1848, the property was bought by Commodore R. F. Stockton, who erected a 40-stamp mill and proceeded to work the mine on a larger scale. His operations extended over a period of about 9 years, and then the mill was burned to the ground. The "Middle" and "Little" veins were worked to a limited extent, but most of the mining was confined to the so-called "Big Sandstone" vein, which averaged about 3 feet in width and in places reached 6 feet or more. The deepest shaft was sunk in the hanging wall about 300 feet from the outcrop and is reported to have reached a depth of 136 feet, but the other openings would not average 45 feet, and practically all of the ore came from above the water level. Starting from a small branch that crosses the outcrop, a tunnel was driven along the vein, and nearly all the stoping was above this level. These old workings are now mostly caved, but they can be traced across the property on the surface for a distance of about 1,500 feet along the strike.

Many remarkable tales cluster about the name of Commodore Stockton and the fortunes said to have been made by him in Virginia gold mines, but few of these can be verified. Estimates of the gold extracted by him from the Tellurium veins vary from \$75,000 to over \$1,000,000, but the lower figure is probably more nearly correct.

After the mill had burned the property was sold and no further work was carried on until after the war. Since that time there have been spasmodic attempts to reopen the mine, but none seem to have been attended with any great degree of success. About the year 1880, a 10-stamp mill with amalgamated copper plates was built, and for a short time the mine was operated under lease. Most of the ore mined at this time was taken from the "Big Sandstone" vein. A few years later the stamp mill was pulled down and replaced by some kind of a revolving mill, which was used to treat ores from the "Gold Hill" veins on the Bowles tract, adjoining the Tellurium on the northeast. About the year 1890, two Tremain steam stamps were installed on the property, but they were never used to any extent.

^aSilliman, B., Remarks on Some of the Gold Mines, and on Parts of the Gold Region of Virginia, Amer. Jour. Sci., vol. xxxii, pp. 98-130.

The last work done on the property was in 1909-1910, when the Argus Gold Mining Corporation cleaned out part of the old workings on the "Big Sandstone" and "Middle" veins, and sank a 3-compartment incline shaft on the "Big Sandstone" to a depth of about 90 feet measured along the dip. Drives were started in either direction along the strike of the vein, but had only progressed a few feet when the mine was closed down. One of the old Tremain stamps was set up again and used in testing a few tons of ore from the "Middle" and "Big Sandstone" veins.

Present underground development.—When the property was examined by the writer in the summer of 1910, the "Big Sandstone" vein was exposed by the new 90-foot incline with short drives at the bottom, and by an old drain tunnel which had been reopened for a distance of 90 yards along the vein, and which connected with a shallow incline. The "Middle" vein was exposed by an incline shaft 50 feet deep and about 125 feet of drives along the vein, all above water level. A little stoping had been done on the latter vein. While there has been a number of other shafts and openings made at various times, they are not now accessible.

The Tellurium Vein System.

Introduction.—The geological descriptions given below will suffice for all properties located along the line of the Tellurium vein system, and under each mine only such details will be referred to as are not mentioned in the description of the system as a whole. The Tellurium system of veins has been developed almost continuously for a distance of a mile, and prospected at short intervals for 5 miles or more along its line of strike. The greatest amount of development work, however, has been done at the Tellurium and Bowles mines. The only openings accessible, when the area was studied by the writer, were located on the adjoining properties of the Tellurium and Scotia mines; and therefore the detailed geological descriptions will be limited to these two properties; but everything that could be learned concerning development work done elsewhere along the belt, indicates that the general structural relations are everywhere the same, though the veins have proved profitable in only a limited number of localities.

General description of veins and country rock.—The veins belonging to the Tellurium system are situated in a series of fine-grained quartz-mica schists, usually garnetiferous, interbedded with fine-grained, even-granular quartzites, some of which contain much hematite and magnetite. All the gold-bearing veins observed occur either in quartzite beds, which

are very narrow, or in the schists close to them. This series of sedimentaries is bounded on the northeast by a fine-grained granite, which in places, especially near its borders, contains areas of hornblende schist. Exposures are very rare except where openings have been made in prospecting for veins, so it is not possible to trace the exact boundaries of the granite area, but its field relations, the lack of schistosity in most places, and the extensive metamorphism exhibited by the schists in the vicinity, indicate that it is later in origin than the sedimentaries. The granite is exposed within less than half a mile of the Tellurium veins and probably comes much closer. Specimens found on one of the old dumps at the Tellurium indicate that there are probably apophyses from the granite, if not the main mass itself, within a few yards of the veins, and this hypothesis is supported by the extreme metamorphism of the rocks at the few places where they are exposed on the northeast side of the veins.

The veins which have received the greatest amount of attention on the Tellurium property are known as the "Big Sandstone," and "Middle," and the "Little" veins. In addition to these the "Hodges" vein on the Scotia property and several other veins belonging to the system have been prospected to a limited extent.

The so-called "Big Sandstone" vein consists of a bed of quartzite 2 to 6 feet thick, cut in places by irregular gold-bearing veinlets, composed essentially of quartz with more or less feldspar and a little pyrite. (See fig. 12.) The veinlets range up to about 1 foot in width, and in their vicinity the quartzite is often impregnated with a very small amount of pyrite, chiefly along bedding planes, and carries a little gold. This bed of quartzite is remarkably uniform wherever it has been observed, and apparently extends continuously for a distance of 3 miles and possibly farther, but it is probably gold-bearing only in places and where it has been mineralized by the vein-forming solutions. It has an average strike of N. 64° E. and dips at an angle of about 45° toward the southeast.

The outcrop of the "Middle" vein is parallel to the "Big Sandstone" and located about 30 feet southeast, dipping in the same direction at an angle of 43°. Where exposed it consists of a series of lenses varying from 3 feet down to a knife edge in thickness, and is composed of quartz with variable amounts of feldspar, pyrite, largely oxidized to limonite, and a little gold. The lenses are enclosed by a thinly foliated, garnetiferous schist the folia of which conform to the flexures of the vein. (See fig. 13.)

The "Little" vein, which is not at present exposed, is said to parallel the "Middle" vein at a distance of 20 feet to the southeast. Descriptions

indicate that it is similar in character to the "Middle" vein but narrower, averaging less than a foot in width, and richer in gold. The deepest workings on the "Little" vein are said to have attained about 65 feet from the surface, but it usually pinched out before that depth was reached.

A vein known as the "West" vein is exposed by a shaft 40 yards northwest of the "Big Sandstone" vein at the Tellurium. Where exposed it has a strike of N. 27° E., a dip of 80° to the east, and is about a foot wide. Quartz found on the dump yielded colors of free gold on panning. The nonconformity of this vein in strike and dip with the other veins of the Tellurium system, suggests that it may belong to the Gold Hill system described on pages 176-179, but the shaft was partly caved and the vein and wall rock could not be examined closely.

The so-called "Hodges" vein, developed to some extent on the Scotia property, is a lenticular bed of ferruginous quartzite, which narrows from a width of over 6 feet to a fraction of an inch within a distance of only 40 feet. The quartzite is cut by a few small stringers of gold-bearing quartz, which have mineralized the enclosing rock to a limited degree. While this quartzite pinches out and is not continuous in its course, as is true of the "Big Sandstone" bed, pieces of float similar in every way are plentiful at several points in approximate alignment with one another in a northeast-southwest direction.

At a number of localities on the Scotia, Tellurium, and other properties along the course of the Tellurium vein system, there are bold outcrops of large veins, consisting of massive white quartz carrying a small amount of kaolinized feldspar. Some of these veins are 10 to 20 feet wide and can be traced for several hundred feet along the strike. They are reported to carry traces of gold but none of them have been worked.

The wonderful uniformity and persistence of the bed of quartzite, known as the "Big Sandstone" vein, and hitherto regarded as a true vein, has given rise to a mistaken idea concerning the continuity of the veins in this district. The "Little" vein and the "Middle" vein and even the gold-bearing stringers in the "Big Sandstone" vein itself, are not continuous for great distances, though it is probable that sections across the vein system, at two or more points, would intersect approximately the same number of veins; for while the veins frequently pinch out, they may be replaced by others a little to one side or farther along the line of strike.

Detailed descriptions of veins and wall rock.—The sketch given in fig. 12 shows the appearance and structural relations of the "Big Sandstone" vein in the northeast drive from the bottom of the new incline shaft at

the Tellurium mine, which is about 65 feet from the surface; and this occurrence is typical of the vein wherever it could be observed. Here the quartzite bed is 6 feet thick, and distinctly laminated parallel to the bedding, the laminae being disturbed in places where the quartz veinlets cut across them. At the top of the bed the quartzite grades into a fine-grained quartz-sericite schist, and finally into the garnetiferous schist which forms the foot-wall of the "Middle" vein; but at the bottom the contact with the underlying rock is sharp and well defined. Below the quartzite there is a bed 4 to 5 inches thick, consisting for the most part of biotite, often altered to chlorite, large garnets, and a little feldspar. The rock underlying this bed is exposed for a short distance only. It is highly laminated and finer grained, but in mineral composition resembles the rock above except for the presence of more quartz. Detailed petrographic descriptions of all of these rocks are given below.

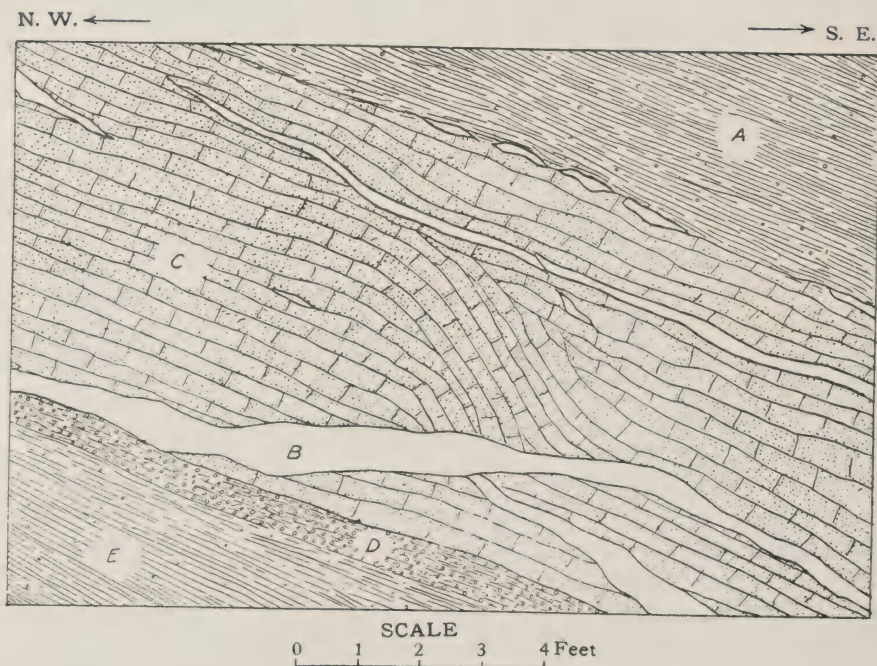


Fig. 12.—Sketch of quartzite bed cut by gold-bearing veins, Tellurium mine. A, hanging wall schist; B, quartz-feldspar veins; C, quartzite; D, garnetiferous foot-wall layer; E, foot-wall schist.

The individual veinlets in the quartzite range up to 14 inches or more in width, and commonly follow bedding planes though they frequently cut directly across. Where the bedding planes are cut by veinlets, little spurs from the quartz sometimes extend out along them for a short distance. Lenses of vein quartz occasionally take the place of veinlets at the top of the quartzite, but rarely occur within the bed itself, and where seen were always small. The veinlets are composed essentially of white to translucent, coarsely crystalline quartz, and kaolinized feldspar is usually present, in places becoming an important gangue mineral. Pyrite is commonly a constituent in small quantity but rarely exceeds one per cent.; native gold occurs in small grains and scales that may usually be detected on panning the crushed ore; and sphalerite, tetradymite, and tellurium (?) have been identified as rare accessory minerals. In the oxidized zone near the surface, joint planes and fractures in the quartz are frequently stained with black oxide of manganese.

The feldspar is distributed throughout the quartz veins in small angular shapes, but is more plentiful near the border portions where it sometimes forms small lenticular bands or streaks parallel to the walls, and may constitute as much as 10 per cent. of the mass. Rarely it occurs in lenticular masses 3 inches or more in maximum diameter. In most places where the vein is exposed the feldspars are completely altered to kaolin, and it is difficult to obtain specimens sufficiently fresh to admit of their determination.

The freshest feldspars were obtained from a piece of vein quartz found on a shaft dump at the Scotia mine, and which evidently came from the foot-wall side of the quartzite bed, for some of the underlying rock was firmly attached. In the hand specimen (143-A) the feldspars occur in somewhat angular individuals ranging up to 0.75 cm. in diameter, and are white to light yellow in color and show good cleavage. While sparingly scattered throughout the quartz they are more plentiful near the contact with the country rock, forming perhaps 10 per cent. of the mass. A little chlorite, occurring chiefly near the contact, white mica and an infinitesimal amount of pyrite make up the chief minor constituents. A few thin plates of ilmenite occur in the quartz near the wall rock. Under the microscope the feldspars show extreme alteration to kaolin and sericite, but multiple twinning can be detected on some of them, and this with the index of refraction identifies them as oligoclase-andesine.^a There is probably some

^aThe indices of refraction as determined by Dr. E. S. Larsen, Jr., using the immersion method, were $\alpha = 1.542 \pm 0.003$ and $\gamma = 1.551 \pm 0.003$.

orthoclase present but it could not be positively identified. The quartz in the slide shows some optical distortion and contains numerous gas- and liquid-filled cavities.

Pyrite nowhere seems to be an abundant constituent of the veins cutting the quartzite. It is usually present in small quantities, rarely amounting to more than 1 per cent., and wherever observed was fine-grained.

Gold occurs chiefly in the native state and can frequently be detected by panning. In a piece of the vein quartz obtained within 6 feet of the surface, close to the incline shaft at the Tellurium mine, gold is present in small flakes about 0.25 mm. in diameter. At greater depth much of the gold is probably contained in pyrite.

A small amount of black sphalerite was identified in vein quartz from one of the stringers in the quartzite, but this mineral seems to be very rare in the veins of the tellurium system.

Tetradymite has been identified in ore at the Tellurium mine, being first analyzed by Coleman Fisher, Jr.,^a and later by Dr. F. A. Genth.^b The analysis given by the latter is as follows:

Analysis of tetradymite from the Tellurium mine, Virginia.

(Dr. F. A. Genth, analyst.)

	Per cent.
Bismuth	51.56
Tellurium	49.79
Selenium	trace
Sulphur	none

Genth states that in the specimen examined by him tetradymite occurs "in broad folia, sometimes 1 inch in diameter, implanted in a decomposed micaceous slate. . . . Before the blowpipe it fuses readily giving out a faint but distinct odor of selenium, leaving on charcoal white incrustations with a yellow center." Elsewhere he states that the tetradymite from the Tellurium mine is frequently interlaminated with gold, and experiments made by him proved that gold was easily precipitated from dilute solutions by tetradymite.^c His description of the gangue indicates that the specimen was probably obtained from the wall of the "Middle" or "Little" vein, rather than the veinlets in the quartzite bed, but these veins are all identical in their mineral composition and mode of formation.

^aAmer. Jour. Sci., vol. vii, 2d ser., p. 282.

^bGenth, F. A., Contributions to Mineralogy, Amer. Jour. Sci., 1855, vol. xix, 2d ser., pp. 15-16.

^cGenth, F. A., Contributions to Mineralogy, Amer. Jour. Sci., 1859, vol. xxviii, 2d ser., pp. 254-255.

Tellurium is mentioned by Credner as being present in the form of a coating together with gold, but the mineral seen by him was probably tetradymite.^a

In order to show the distribution of the gold and the relative degree of mineralization, average samples of the veinlets and of the quartzite were carefully taken in the face of the drive sketched in fig. 12. The elements, gold, silver, iron, and sulphur, were determined in each of these samples and are tabulated below. The percentage of pyrite given in the table was computed from the amount of sulphur found, based on the assumption that all of the sulphur present is in the form of pyrite, which is essentially correct. The excess iron is present chiefly in the form of limonite, with a little chlorite, and possibly some ilmenite.

Partial analyses of ore from the Tellurium mine, Virginia.

(E. E. Burlingame & Co., analysts.)

	Vein quartz.	Quartzite.
Gold (ounces)	0.12	0.02
Silver (ounces)	trace	....
Iron (per cent.)	1.00	3.60
Sulphur (per cent.)	0.16	0.41
Pyrite (per cent.)	0.30	0.77

The quartzite which forms the greater portion of the "Big Sandstone" vein is fine-grained, even-granular, and light gray to almost white when fresh, turning to light brownish-gray or pink on weathering. The rock has distinct schistosity parallel to the bedding, and when examined on fractures that cut across the schistosity it appears to consist entirely of quartz, while on surfaces paralleling the schistosity fine scales of sericite can always be distinguished and are usually abundant, giving the quartzite a high luster. A little fine-grained pyrite may be recognized in places, but is never an important constituent. In a single instance, crystals of muscovite over 2 cm. in diameter were found in quartzite adjacent to one of the veinlets.

In thin sections (Specs. 135, 147, and 189) under the microscope, the quartzite is composed essentially of interlocking quartz grains, less than 1 mm. in maximum diameter and averaging about 0.25 mm., which are partially oriented with their greater diameters roughly parallel to the schistosity. The quartz grains are so extensively recrystallized that they

^aCredner, H., Report of Explorations on the Gold Fields of Virginia and North Carolina, Amer. Jour. Mng., 1869, vol. vii, p. 9.

furnish little evidence of their former size and shape. They usually show some optical distortion but little if any granulation, and contain occasional small fluid inclusions. Sericite is always present in small scattered flakes mostly parallel to the schistosity. The feldspars (orthoclase and acid plagioclase) are common in specimens of quartzite obtained near the veinlets, and seem to be rare or absent elsewhere in the quartzite. Where abundant the feldspars occur filling interstitial spaces between quartz grains, and in long, irregular, more or less broken lines parallel to the schistosity, indicating that they were formed later than the quartz, and suggesting that the feldspars may have been introduced into the rock by the vein-forming solutions. The feldspars are partly kaolinized and show some alteration to sericite. The alteration of the feldspars together with their low index of refraction render easy their differentiation from quartz even where twinning is absent. The minerals chlorite, zircon, titanite, rutile, and ilmenite, partly altered to leucoxene, are present in small but varying quantities as unimportant accessory constituents.

The contacts between the stringers of vein quartz and the quartzite are well marked and easily recognized in the hand specimen because of difference in color and granularity, but under the microscope (Spec. 190) the contact is less sharply defined and is more of a gradation. The quartzite is completely recrystallized, so that the individual quartz grains interlock with those of the vein quartz, and the only difference between them is one of relative size. In the former the grains are seldom over 1 mm. in diameter, while in the latter the quartz individuals average from 2 to 3 mm. The quartz grains in both vein and quartzite show irregular, interpenetrating boundaries, strain shadows, and slight peripheral granulation. The vein quartz is practically free from impurities other than minute gaseous and liquid inclusions. The quartzite contains much feldspar, chiefly orthoclase with some acid plagioclase, which shows slight kaolinization and partial alteration to sericite. Sericite in small flakes is distributed throughout the quartzite, pyrite is present, usually in small cubes, and the minerals chlorite and zircon occur as minor constituents.

A specimen (188) found on an old dump at the Tellurium mine, contains a layer of rock 3.5 to 4 inches thick, which consists of fine-grained, impure quartzite, or schist interleaved with numerous narrow veinlets and lenticular eyes of quartz 1 mm. to 1 cm. in width. This layer was interbedded with the normal quartzite. Microscopic examination shows that the veinlets and lenses are composed chiefly of coarsely crystalline quartz.

with minor amounts of feldspar—albite or albite-oligoclase and perhaps some orthoclase. The quartzite is very fine-grained and consists of quartz, feldspar, sericite, biotite, chlorite, pyrite, and a little titanite. The feldspars in the veinlets frequently have good crystal outline and range up to 1 mm. or more in diameter. They usually occur near the border portions of the veinlets projecting into the fine-grained quartzite, and in places appear to be completely separated from the veinlets. These feldspars, while well formed, show rough outlines under the microscope, because along their boundaries the feldspars fill up the inequalities caused by irregularities in the adjoining quartz grains. Some of the feldspars show albite twinning but many are unstriated.

By decrease of quartz and increase of mica the quartzite passes into the overlying schists. In the hand specimen (141) the rock from the hanging wall of the "Big Sandstone" vein, where it was cut by a vertical shaft at the Scotia mine, is a light brown, fine-grained, schistose quartzite; and in thin section under the microscope it is even-granular, being composed of roughly rounded quartz grains, showing little or no optical distortion, and decreasing amounts of biotite, sericite, and chlorite. There is probably a little feldspar present, but it could not be positively identified. Some of the biotite shows partial alteration to chlorite. The minor accessory minerals are a little pyrite, chiefly along bedding planes, small grains of ilmenite, largely altered to leucoxene, and occasional inclusions of zircon and rutile.

Another specimen (142) from the same locality is a fine-grained, light gray schist composed chiefly of quartz and sericite with scattered flakes of biotite and chlorite, and occasional garnets 1 to 3 mm. in diameter. Other minerals present are pyrite, zircon, titanite, and leucoxene.

Between the quartzite and the middle vein the rock is mostly a fine-grained, light bluish-gray schist composed essentially of quartz, sericite, and biotite. In places it contains impure garnets 1 to 2 mm. in diameter, and sometimes there is much fine-grained pyrite present.

The thin strip of rock underlying the quartzite (see fig. 12) in many ways resembles the garnetiferous bed that occurs on the east side of the quartzite near New Canton (see pp. 107-108), and elsewhere, except that no sillimanite or cyanite could be identified in the rock at the Tellurium mine. In color the rock varies from dark gray where freshest to dark brown or greenish-brown. It consists chiefly of numerous reddish-brown garnets ranging up to 5 mm. in diameter, imbedded in a schistose ground-mass of biotite usually altered to chlorite. In thin sections (Specs. 186-A and -B)

under the microscope much feldspar—both acid plagioclase and orthoclase—can be distinguished, and the minerals, quartz, ilmenite, mostly altered to leucoxene, pyrite, and sericite, are also present. The garnets occur in well-formed dodecahedrons containing inclusions of ilmenite and leucoxene. The biotite is light brown in color and in some specimens is largely altered to chlorite. The feldspars are extensively kaolinized, contain inclusions of biotite and chlorite, and in places show albite twinning.

This strip of foot-wall rock was encountered at the Bowles and Scotia mines as well as at the Tellurium. Pieces of vein quartz were found on the dump at the Bowles mine with some of the foot-wall adhering, which contained garnets over 1 cm. in diameter, partly imbedded in the vein quartz and partly in the wall rock.

At the Scotia mine dark green hornblende is found in places where the vein quartz, containing feldspar, occurs in contact with the rock underlying the quartzite. Occasionally small veinlets extend from the quartz vein out into the country rock and these carry much feldspar, white to yellow in color. The hornblende is present in the wall rock close to the vein, sometimes being the chief constituent, and does not seem to extend farther than 3 or 4 inches from the contact with the vein. This hornblendic rock grades into the normal biotite-chlorite-garnet schist described above. Examined microscopically (Spec. 143-B) the hornblende is light green to colorless, and shows alteration to chlorite and epidote. Quartz occurs in irregular grains showing optical distortion. Much titanite is present in clear, light pink to colorless grains, well-formed crystals of rutile occur as inclusions in the quartz, and ilmenite is also a minor constituent. Both rutile and ilmenite show partial alteration to leucoxene.

A specimen (194) of the rock underlying the narrow strip described above was obtained in the face of the northeast drive from the Tellurium incline shaft (*E* in fig. 12). It is a light brown schist similar in mineral composition to the overlying rock, except that it is finer grained and more siliceous. The minerals present are quartz, biotite and chlorite, garnet, feldspar, sericite, pyrite, leucoxene derived from ilmenite, and titanite, the order given being that of relative abundance. The quartz grains are small and show little optical distortion. Biotite is present in brown flakes containing occasional inclusions of quartz, and is extensively altered to chlorite. The garnets are light pink in color and show slight alteration to chlorite along fractures. They contain numerous inclusions of quartz, pyrite, and ilmenite partly altered to leucoxene. The feldspars—orthoclase and acid plagioclase—are extensively kaolinized.

The "Middle" vein is conformable in strike and dip with the enclosing schists, and therefore parallel to the quartzite bed. It is extremely variable in width, consisting of a series of small lenses which range up to 3 feet or more in thickness; and these lenses are all strung out along the same line, being usually connected by a narrow stringer. (See fig. 13.) In this respect the "Middle" vein is markedly different from the veinlets in the

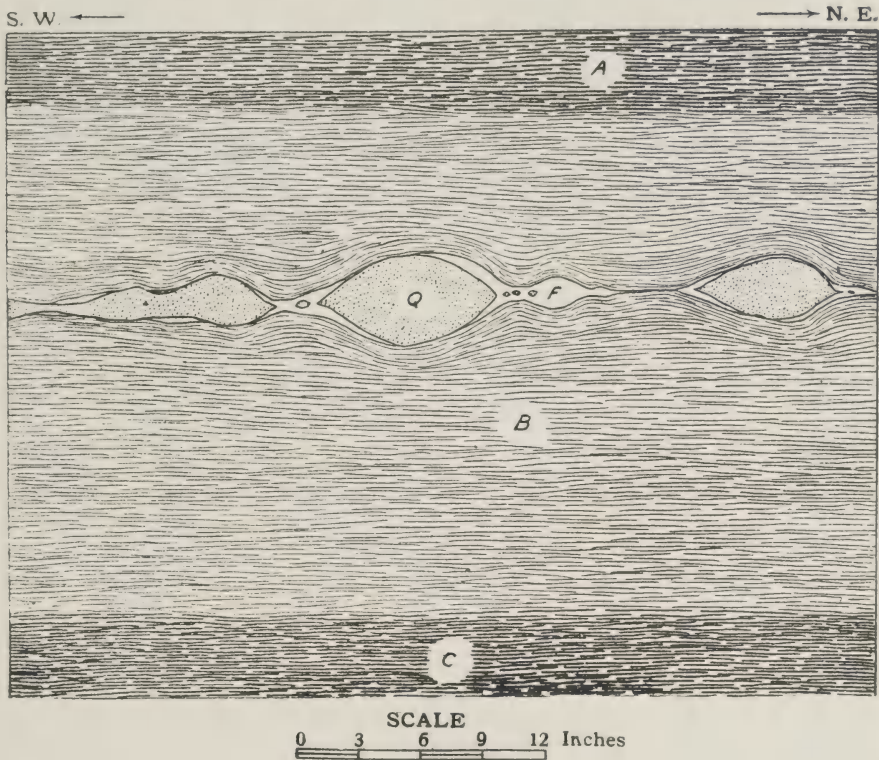


Fig. 13.—Diagrammatic sketch showing symmetrical lenses of the middle vein at the Tellurium Mine. *Q*, quartz; *F*, feldspar; *A*, hanging wall schist; *C*, foot-wall schist; *B*, bed of light-colored schist.

quartzite, for the latter are seldom lenticular in shape, frequently cut across the bedding of the enclosing rock, and are variable in their strike and dip.

The lenses forming the "Middle" vein are separated in places by a distance of several feet, and the veinlets connecting them may pinch to almost nothing so that only a faint line remains, but it can usually be distinguished without difficulty. In the partly decomposed schists near the

surface this line is marked by the dark stain of oxides of iron, probably from the alteration of pyrite; and when the soft material is broken away a little coarse grit, due to the presence of quartz, can be detected on the line.* Feldspar is an important constituent of this vein, but in the openings that are now accessible it is completely altered to kaolin. The kaolin

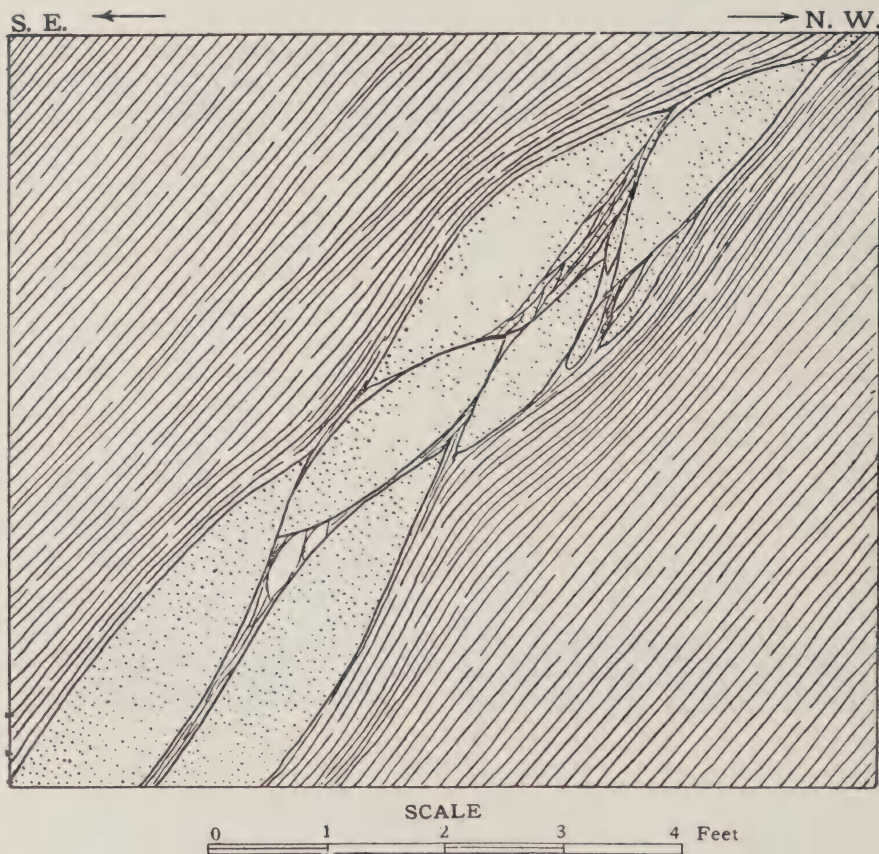


Fig. 14.—Vertical section of middle vein at the Tellurium Mine, showing large lens composed of smaller lenses.

occurs in small angular shapes distributed throughout the quartz, but is mostly found along the border portion of the lenses, and especially at points where they narrow and pinch out. (See fig. 13.) Some of the smaller lenses 2 or 3 inches in length are composed entirely of kaolin. In places the larger lenses are made up of a number of smaller ones as shown

in fig. 14, and where this occurs there is occasionally a little schist included between the component lenses. At one point the vein is cut by a vertical fault which displaces the vein about 2 feet. (See fig. 15.)

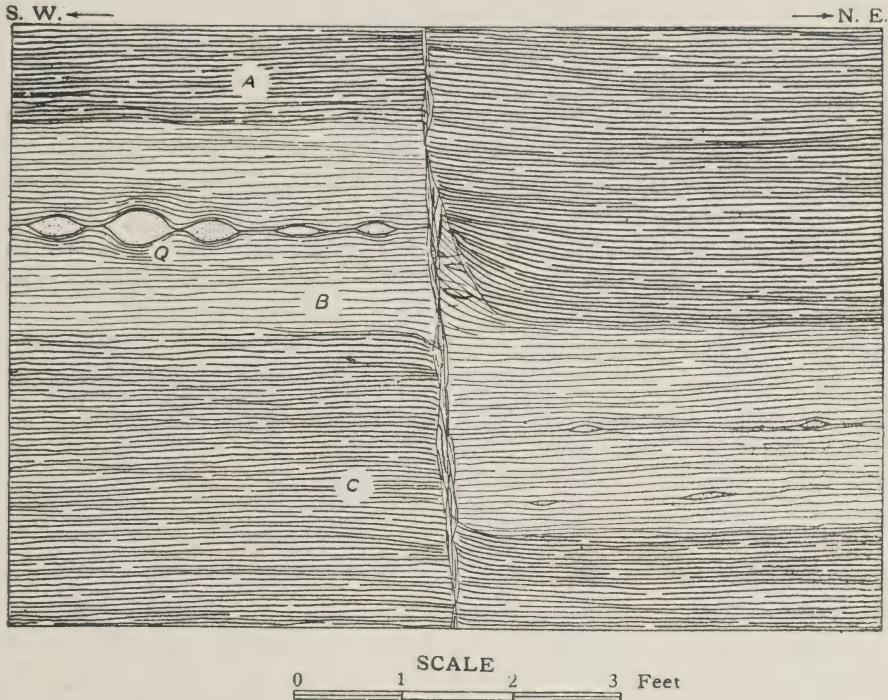


Fig. 15.—Vertical section showing symmetrical lenses of the middle vein of the Tellurium Mine, and a small fault. *Q*, quartz-feldspar lenses; *A*, hanging wall schist; *C*, foot-wall schist; *B*, bed of light-colored schist.

The formation of the peculiar lenses which constitute the “Middle” vein is discussed in detail in the chapter on genesis, pages 224-230, and therefore nothing further concerning them will be said here.

The “Middle” vein is similar in mineral composition to the veinlets that cut the quartzite bed and constitute the chief gold-bearing portion of the “Big Sandstone” vein, but it probably contains a larger percentage of feldspar. According to report, the “Middle” vein is much richer in gold than the “Big Sandstone,” and this is unquestionably true if the whole bed of quartzite is included with the veinlets, but it is questionable whether the average value of the gold-bearing veinlets that occur in the quartzite is greatly below that of the “Middle” vein. An average sample,

taken across a lens in the vein $2\frac{1}{2}$ feet wide, yielded \$2.07 gold per ton, but it should be understood that this does not represent the average value of the vein. The best ore seems to occur in pockets or shoots, and much of the ore that has been stoped out unquestionably carried high values in gold. An ore pile on the surface showed much gold when tested by panning, and specks of visible gold are not infrequent in fragments of the ore. The wall rocks apparently are not mineralized to any appreciable extent.

The "Middle" vein is enclosed in a series of fine-grained, knotted schists, containing pseudophenocrysts of garnet. The folia of the schists in the immediate vicinity of the vein are wrapped around the lenses, conforming to every curvature of the ore-body, but in passing away from the vein the flexures gradually disappear, and at a short distance the folia are straight and undisturbed. (See fig. 13.)

The vein appears to follow a bed of light-colored schist 2 to $2\frac{1}{2}$ feet thick interbedded with darker schists. Where exposed these rocks are so badly altered that it is not possible to obtain material sufficiently fresh for microscopic examination. The light-colored schist is composed essentially of quartz and sericite, with small, scattered brown spots due to the alteration of garnet. Along fractures and joint planes it is stained with iron, but elsewhere it is almost white in color. The overlying schist is light bluish-gray, and contains decomposed garnets 3 or 4 mm. in diameter, embedded in a fine-grained ground-mass. The folia of the schist are wrinkled or folded to form lenticular eyes around the garnets. The underlying schist is similar to the one last described excepting that the garnets are less numerous and smaller in size.

Pieces of unaltered garnetiferous schist, similar to the decomposed schist described above, were found on the dump of the 136-foot vertical shaft sunk in the hanging wall of the Tellurium veins. In the hand specimen (178) it is a thinly foliated, fine-grained, bluish-gray rock with high luster on surfaces parallel to the schistosity, and is spotted with numerous garnets in well-formed dodecahedrons 1 to 2 mm. in diameter. With the aid of a pocket lens, quartz, sericite, and biotite may be identified as the chief minerals of the ground-mass. Under the microscope the garnets are seen to be full of small inclusions consisting of grains of quartz, ilmenite partly altered to leucoxene, and a black opaque mineral in dust-like particles, possibly ilmenite. The ground-mass is composed of small irregular grains of quartz, with flakes of sericite, biotite, and chlorite, all of which are crowded with the black dust-like inclusions. Leucoxene is plentiful in grains which frequently contain nuclei of unaltered ilmenite.

Occasionally the garnets are partly or wholly surrounded by a zone from which most of the minerals other than quartz have disappeared, probably entering into the composition of the garnet; and the quartz has recrystallized into small, elongated grains, with their longer diameters oriented in approximate alignment with radii extending from the garnet. (See Pl. V, fig. 2.)

Pieces of rock, evidently igneous in origin, were found on the dump of an old shaft, which was sunk in developing the "Big Sandstone" vein at the Tellurium mine, but is now completely caved. In the absence of chemical analyses or knowledge of the structural relations, it is impossible to definitely classify this rock, but it is not improbable that it is genetically related to the granite on the northwest. In the hand specimen (185) the rock is light gray in color, fine-grained, and very schistose. Roughly formed, reddish-brown garnets and small flakes of biotite can be distinguished in a white ground-mass composed of quartz and feldspar. Examined in thin section, feldspar phenocrysts are seen, ranging up to 2 mm. in length, which, with flakes of biotite about 0.5 mm. in length and irregular garnets, occur in a fine-grained ground-mass composed of quartz, feldspar, biotite, a little sericite, and inclusions of leucoxene, zircon, titanite, and rutile needles. The feldspars are acid plagioclase (albite-oligoclase (?)) and orthoclase, the larger individuals have very irregular outlines, and they contain numerous fluid-filled cavities and small inclusions of zircon and the titanium minerals.

A different appearing igneous rock found on the same dump is much more schistose than the one previously described, and may represent an interbedded acid extrusive, or a dike rock older in age than the granite and its differentiates. It contains numerous garnets 1 to 2 mm. in diameter and flakes of biotite, embedded in a light brown, schistose ground-mass, composed essentially of feldspars, more or less kaolinized. Examined under the microscope the garnets are very ragged in outline and contain numerous inclusions of quartz. Feldspars, chiefly soda plagioclase, are dominant in the thin section, though a little orthoclase is present. Some of the larger feldspars are bent and broken, the fractures being filled by minerals of later crystallization. The minor constituents are quartz, pyrite, and leucoxene.

The hypothesis that these rocks are genetically connected with the granite is strengthened by the presence on one of the dumps of hornblende schists, such as are found in the immediate vicinity of granite throughout the area. A hand specimen (179) of hornblende schist found

on the dump of the 136-foot shaft at the Tellurium mine, consists of coarse-bladed crystals of dark green hornblende ranging up to 1.5 or 2 cm. in length, and white, fine-grained quartz and feldspar. Small grains of pyrrhotite, pyrite, and magnetite are plentifully distributed throughout the rock. Under the microscope the hornblende is ragged in outline, and micropoikilitic in texture from numerous inclusions of quartz, magnetite, and pyrite. The cleavage is well developed and they are usually dark green in color, though some are nearly colorless. The quartz occurs in small rounded grains and is difficult to distinguish from the unstriated feldspar. The latter is acid plagioclase; probably no orthoclase is present in the rock. Magnetite is plentiful in small idiomorphic grains. Calcite and fibrous serpentine occur as vein-filling in a microscopic fracture.

Another variety found on the same dump is much finer grained. It is a greenish-gray schistose rock (Spec. 180) in which quartz, hornblende, magnetite, pyrite, and a little sericite can be distinguished with the aid of a pocket lens. In thin section the hornblende occurs, partly in dark green to colorless crystals with well-developed cleavage and strong absorption in the darker varieties, and partly in nearly colorless needles often clustered together in radiating groups. Quartz and an unstriated feldspar, probably acid plagioclase, are present in rounded grains showing little optical distortion. Much magnetite, in idiomorphic crystals ranging up to 1 mm. in diameter, is plentifully distributed throughout the rock.

The lenticular bed of ferruginous quartzite, known as the "Hodges" vein, which has been developed to some extent at the Scotia mine, is situated about 600 yards southeast of the course of the "Big Sandstone" vein. The few exposures in the vicinity indicate that the quartzite is interbedded with quartz-sericite schists. A small prospect pit, located about 300 yards northeast of the openings on the "Hodges" vein and approximately in line of strike, exposes a thinly foliated schist, which in the hand specimen (211) appears to be composed entirely of sericite and quartz. It is white in color when not stained with limonite, and contains occasional eyes of light blue opalescent quartz about 0.5 cm. in length. The strike of the schistosity is N. 60° E. and the dip 30° toward the southeast.

The shape of the quartzite bed, where it is exposed by short drives from the bottom of the incline shaft, is shown in fig. 16. The maximum width is over 6 feet, and from this the bed tapers down to a fraction of an inch at either end. The average dip is southeast 35° and the strike about N. 40° E. Although the quartzite apparently pinches out at either end of the lens, much float rock identical in appearance and composition occurs on the

surface about three-quarters of a mile northeast, and at several other points in the same general alignment.

Megascopically the quartzite is fine-grained, even-granular, and somewhat variegated in color because of local concentration of the various oxides of iron. In places the rock is white to light gray in color, consisting chiefly of quartz, with only a small amount of iron in the form of specular hematite and octahedral crystals of magnetite. Elsewhere the rock is dark brown

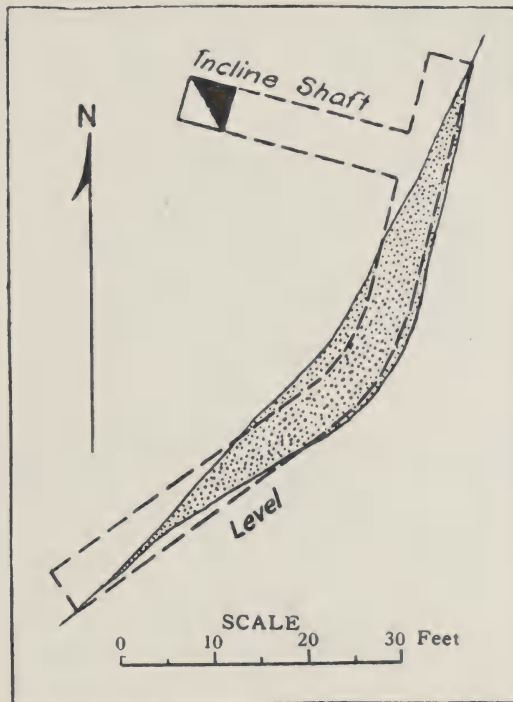


Fig. 16.—Horizontal plan showing lenticular shape of ferruginous quartzite bed exposed in underground openings at the Scotia mine.

to black in color and contains a larger percentage of the iron minerals, which are usually extensively altered to limonite. The two colors are irregularly intermixed, blotches of white being enclosed in areas that are dark brown in color and *vice versa*. Near the center of many of the dark areas, much fine-grained magnetite is found, and along the contact between the light and dark areas there is often a narrow, red-colored band, probably due to iron stain on the quartz grains.

In thin section (Spec. 153) under the microscope the rock is essentially the same as the non-gold-bearing ferruginous, quartzites which occur at a large number of localities in the area, described in detail on pages 19-22. The quartz grains are roughly rounded, nearly uniform in size, averaging about 0.25 mm. in diameter, and show no optical distortion. This close interlocking texture is due to recrystallization, which probably resulted in some enlargement of the individual grains. Small idiomorphic inclusions of martite (magnetite altered to hematite) are present in the quartz; and the larger masses of iron ore, occurring between the quartz grains, show considerable alteration to limonite, which in many places stains the boundaries of the other minerals. Zircon and a few small rutile needles are unimportant minor constituents.

The quartzite is cut by occasional irregular stringers of quartz, which range up to 10 inches or more in width, and very rarely contain vug-like cavities lined with quartz crystals. The stringers occur mostly on the foot-wall side of the quartzite. They carry a little pyrite largely altered to limonite, and probably a small amount of feldspar, though the latter mineral was not positively identified. The presence of gold is easily detected by panning, and sometimes small specks of free gold can be identified in hand specimens, usually in association with limonite derived from pyrite.

Tests made by panning indicate that the quartzite away from the gold-bearing veinlets carries little if any gold. Sometimes a small amount of pyrite may be found in the quartzite near the veinlets, but most of it occurs as a coating along fractures and is evidently secondary in origin.

The Scotia Mine.

Location.—The Scotia property is situated about half a mile north of Caledonia and 7 miles northeast of Columbia. It adjoins the Tellurium mine and is crossed by the southwestern extension of the same vein system.

History and description.—This property was formerly known as the Perkins mine and under that name was prospected in the early days of gold mining in Virginia. According to Credner the ore used to pay the working expenses. After 1849 very little work was done until the Scotia Mining Co. began prospecting in 1910. An account of the development work is given below and a detailed description of the veins and country rock will be found on pages 157 to 172.

A drain tunnel was driven 105 feet in a direction S. 11° E., cutting the "Big Sandstone" vein near the portal and also two small stringers that were called the "Middle" and "Little" veins. The country rock is much decomposed, but where fresh enough for identification consisted of

knotted garnetiferous schists similar to those at the Tellurium mine. A 67-foot vertical shaft sunk in the hanging wall, cut the "Big Sandstone" vein near the bottom. It was partly filled with water when the property was examined by the writer, but much fresh rock was exposed on the dump and this is described, together with the veins of the Tellurium system, on pages 157 to 164. The "Big Sandstone" vein was exposed in a pit sunk on the outcrop 100 feet northwest of the vertical shaft. Here the quartzite bed had a strike of N. 50° E., a dip of 35° southeast, and varied from 8 inches to 3 feet in width, averaging about 18 inches. It is cut by veinlets of massive white quartz carrying considerable kaolinized feldspar. The same vein has been prospected on this property by several other surface cuts.

An old incline shaft near the western boundary of the property was reopened by the Scotia Mining Co. It was sunk on a vein called the "Middle" vein, which has a maximum width of 2 feet about 12 feet from the surface and pinches to an inch near the bottom, 25 or 30 feet from the surface. The strike is approximately N. 60° E. and the dip 35° southeast. The enclosing rock, consisting of knotted, garnetiferous schist, is conformable in strike and dip, and is cut by vertical joint planes, spaced 12 to 18 inches apart, which have a strike of N. 44° W. It is improbable that this vein is continuous with either of the stringers in the drain tunnel or with the "Middle" vein at the Tellurium. Small stringers like these are not as a rule continuous for great distances but pinch out and are replaced by others a little farther along the line of strike.

Near the southwestern corner of the Scotia property there is a bed of ferruginous quartzite cut by small gold-bearing stringers, which is known as the Hodges vein. It has been developed by several surface cuts and an incline shaft on the vein, 43 feet deep, from which short drives were run in northeast and southwest directions. A detailed description of the ore and country rock is given on pages 170-172.

Gold Prospects Southwest of the Scotia Mine.

Passing southwest along the strike of the Tellurium vein system, old prospect holes are found at short intervals as far as Big Byrd Creek, but, while gold has been found at a number of these places, very little development work has been done.

On the Jennings tract adjoining the Scotia there are several old shafts and surface pits located along the strike of the Tellurium veins, but these are now caved and do not seem to have reached a depth of more than 40

feet. Knotted garnetiferous schist, having a strike of N. 60° E. and dip of 30° southeast, is exposed in one of the openings, and quartzite similar to that at the Tellurium mine is present on one of the shaft dumps.

By means of surface cuts, the quartzite bed has been traced across the Mosby, Fountain, and Cocke properties, and placer gravels have been worked along the branches that run through them and enter Big Byrd Creek. It is said that the "Big Sandstone" vein was prospected on the Fountain property in 1837 by Geo. Fisher, and another vein, known as the Marks vein, was also opened and worked to some extent. The ore was crushed in a small 3-stamp mill on Horsepen Creek and yielded \$75 per day.^a

Some mining has also been done on the old Bartlett place in this vicinity. Gold was discovered in the Bartlett Branch, which enters Big Byrd Creek from the east a short distance above Bowles' bridge, and the placer gravels are said to have been worked by the Fishers. Later the Bartlett vein was discovered and prospected and a little mining done. The ore from this vein was carried to Bowles' Mill on Big Byrd Creek and crushed in a small wooden stamp mill operated by the same power that ran the grist mill.

Recently some prospecting has been done on a part of the old Payne farm, now known as Cassell's mine. The place is situated on the county road about 2 miles northwest of Caledonia and 3 miles southwest of Kent's Store. A small amount of ore has been mined and milled but all the work has been of a superficial nature. Several shafts and cross-cuts, all above water level, have been sunk in decomposed rock, and the only veins exposed when the openings were examined by the writer, consisted of a few quartz stringers less than an inch in width. Part of the workings are in a decomposed dike-like rock about 20 feet wide which appears to be pegmatite. It is not well exposed but has a probable strike of N. 6° E.

Close to the other openings a pit has been sunk on a highly ferruginous quartzite bed 8 feet or more in thickness. The quartzite is dark brown with occasional light-colored spots, and is cut by closely spaced joints. It is composed of fine-grained quartz, hematite, and a little magnetite, and the light spots seem to be due to recrystallization of silica. In places along cracks or cleavage planes a crust of magnetite has been formed consisting of crystals 2 to 3 mm. in diameter. The quartzite is cut by quartz veinlets 1 to 2 inches in width which frequently contain plates of micaceous

^aCredner, H., Report of Explorations on the Gold Fields of Virginia and North Carolina, Amer. Jour. Mng., 1869, vol. vii, pp. 42-43.

hematite. Examined under the microscope (Spec. 209) it seems to have undergone greater recrystallization than the other ferruginous quartzites of the area. The quartz grains lack uniformity in size and are irregular in outline; they usually show optical distortion and contain comparatively few inclusions of the iron ores, while the larger masses of hematite contain small inclusions of quartz. The iron ores are partly altered to limonite, and the latter in places stains the contacts between the quartz grains.

The Bowles Mine.

Location.—The Bowles property is situated $1\frac{1}{2}$ miles southeast of Tabscott and about 8 miles northeast of Columbia. It lies east and northeast of the Tellurium mine, and embraces a large area of land in both Goochland and Fluvanna counties.

History and general description.—The placer gravels along the two branches that run through the property were extensively worked for gold prior to the Civil War. After the veins of the Tellurium system had been developed on the property of that name, they were traced across on to the Bowles tract and prospected at several points. Prospecting has been renewed at several different periods and considerable development work carried out. A shaft started on the outcrop of the "Big Sandstone" vein was sunk about 100 feet on the dip of the vein, and 50 feet from the collar a cross-cut was driven southeast to connect with a vertical shaft at a point about 40 feet below the surface. The vertical shaft was sunk to a depth of 72 feet, and after striking the "Little" vein was continued for 45 feet along the dip of the vein. When visited by the writer in 1910 the shafts were partly filled with water and all the workings inaccessible. The data given above were furnished by Mr. Ferris, who was in charge of the property at the time. The character of the veins and the structural relations of the wall rock, which are the same as at the Tellurium mine, are described in detail on pages 157 to 172.

The Gold Hill vein system crosses the northwestern end of the Bowles property, and several of the veins belonging to it were prospected at an early date. A number of shafts and other openings have been made, but practically all of them are now caved. The most extensive workings are located on the Gold Hill vein, and the Shaw or Back Field vein. Ores from the former vein were hauled to the Tellurium mill for treatment when mining was in progress about 25 years ago. A little work has been carried on recently by Mr. Ferris, who mined a few tons of high-grade ore from a small opening on the Back Field vein and crushed it in the Tellurium mill. The veins belonging to the Gold Hill system are described in detail below.

The Gold Hill Vein System.

Introduction.—The Gold Hill vein system is situated about 2 miles southeast of Kent's Store and 2 miles west of Tabscott, and extends for a mile or more in a general northeast-southwest direction. It consists of a series of small veins, which show a greater variation in strike and dip than is found elsewhere in the district, but none of them seems to be very persistent. The veins have been developed to some extent at several places on the Bowles, Shaw, and McGloam properties, but all the work has been rather superficial in its nature. These veins differ from other veins of the district in several important characteristics besides their lack of uniformity in strike and dip. They are located in an area of fine-grained granite, and are the only known gold-bearing veins within this district that occur in granite. The veins are characterized by the presence of coarsely crystalline pyrite, which frequently occurs in large cubical shapes 1 cm. or more in diameter.

Country rock.—There are few exposures of the country rock except where openings have been made in prospecting the gold veins. The dominant rock is a fine-grained granite, and this contains areas of hornblende and chlorite schists, which are more noticeable near the border portions. Because of the extensive decomposition of the rocks in this section it is not possible to accurately map the boundaries of this granite area, but it has a width of more than one mile, and extends for an unknown distance in a northeasterly direction, probably connecting with the main granite batholith that lies to the east.

The granite where freshest is a light gray, fine-grained rock, with scarcely any schistosity. The minerals visible to the naked eye are quartz and feldspar, with numerous small flakes of dark green chlorite, a little sericite, small cubes of pyrite, and occasional grains of magnetite. In thin sections it varies from granitic to granophyric in texture, intergrowths of quartz and the feldspars being common, and in places very abundant, while small phenocrysts of feldspar are present in some of the rock. The feldspars are acid plagioclase and orthoclase, with sometimes a little microcline. The white mica is apparently all secondary, and frequently shows intergrowths with quartz. The chlorite is probably derived from biotite, a mineral which is present in small quantities only. Calcite is plentiful in some slides and is probably derived chiefly from the feldspars. The minor constituents occurring in the rock are zircon, leucoxene, apatite, and rutile needles, while fluid inclusions are numerous in some of the quartz grains. (Specs. 82, 83, 158, 161, and 166.)

The hornblende schist is exposed at several points in narrow bands interleaved with granite, and also in areas at least several hundred feet across. These schists are similar to the corresponding schists in the larger granite area, and are doubtless the same in origin. The rock is dark green in color and varies from medium coarse- to fine-grained. Hornblende, often largely replaced by chlorite, quartz, and feldspars, are the chief constituents; pyrite and magnetite can usually be recognized megascopically; and in some of the rock small grains of rutile and ilmenite can be identified. Under the microscope the larger hornblendes are ragged in outline and micropoikilitic from numerous inclusions of quartz and magnetite. The feldspars (acid plagioclase) are clear, unstriated, and difficult to distinguish from quartz except by their lower index of refraction. Occasional grains of titanite, inclusions of zircon, and small rutile needles constitute the minor accessories. (Specs. 80, 81, 159, 160, 165, and 167.)

Granite is the principal rock composing the dumps from shafts sunk on veins belonging to this system, and the hornblende schist is present in smaller amounts or entirely absent.

The McGloam mine.—The McGloam mine is situated half a mile north of the Tellurium and joins the Bowles property which lies to the east. There are 2 shafts on the property 300 yards apart, one vertical and the other on a flat incline, but both are now filled with water. A vein, 1 to 2 feet wide, is exposed in the mouth of the incline shaft. It has a strike of N. 70° E. and dips southeast at an angle of 30°. The fine-grained granite, a little hornblende schist, and considerable vein quartz are present on the dump.

The vein quartz contains much coarsely crystalline pyrite, and in some pieces this has been partly or wholly removed, leaving cavities in the quartz which frequently show no staining from oxides of iron. A little free gold can sometimes be detected by panning. In places the vein quartz is interleaved with narrow bands of fine-grained granite which in the hand specimen resembles quartzite, for it contains practically no ferromagnesian minerals. A thin section (162) examined under the microscope, contains a veinlet of quartz 3 mm. wide enclosed by granite. The veinlet has sharply defined boundaries and is composed of quartz, containing numerous fluid inclusions, a very little feldspar, and some sericite. The enclosing rock is granitic to granophyric in texture, and consists of irregular rounded grains of quartz and feldspar, with a fine intergrowth of feldspar and quartz filling the interstitial spaces. The feldspar is chiefly acid plagioclase, usually showing albite twinning, but orthoclase is also present and

occasionally forms Carlsbad twins. A few flakes of sericite, small, scattered grains of magnetite, inclusions of zircon, and minute rutile needles make up the minor accessory minerals. A piece of granite found on the dump was cut by a stringer of quartz 1 inch in width, which contained small vugs lined with quartz crystals.

Fine-grained granite and vein quartz were found on the dump of the vertical shaft, but no hornblende schist. The vein quartz (Spec. 162) contains coarsely crystalline pyrite, and angular inclusions and irregular streaks of the country rock. The inclusions, which are often large, give to the weathered rock the appearance of pegmatite. They are composed essentially of fine-grained feldspar and quartz which under the microscope are seen to be closely intergrown. The vein quartz shows little optical distortion and contains numerous fluid inclusions, usually arranged in long, broken lines which may pass without interruption from one individual to another.

The Shaw mine.—The Shaw property is situated $1\frac{1}{2}$ miles northeast of the Tellurium mine, and on the east side of the northern portion of the Bowles tract. There are several shallow shafts located close to the small branch which passes through the property, but they are now partly caved and filled with water. They are said to have been sunk on the Shaw vein which has a strike of N. 80° E. Granite and hornblende schist were found on the dump, and the former rock outcrops at several places in the vicinity.

The Bowles mine.—The Bowles property is described on page 175, and therefore only the veins belonging to the Gold Hill system will be mentioned here.

Near the northern end of this property there are several pits and small shafts, which are said to have been sunk on the "Shaw" vein, or "Back Field" vein as it is sometimes called. Only one of the openings was accessible when the property was examined by the writer, and this was not over 30 feet in depth. The vein where it is exposed varies from 1 foot down to a fraction of an inch, but Mr. Ferris, who was in charge of the property, states that in places it attains a width of 4 feet. The strike is about N. 60° E. and the dip 30° southeast, so it is hardly probable that this vein is the extension of the one opened on the Shaw property. In places the vein carries considerable pyrite, partly altered to limonite, and at such points it is said to be rich in gold. A specimen examined by the writer contained grains of gold 2 mm. in diameter. Some of the vein quartz found on the dump contains cavities, evidently left by the oxida-

tion and removal of pyrite, for some of them are partly filled with limonite; and attached to the walls of these cavities are numerous octahedra of magnetite 1 mm. and less in diameter. The wall rock where exposed consists of kaolin and quartz stained with a little iron, and is undoubtedly residual decay from the fine-grained granite found elsewhere in the vicinity.

About 500 yards south, a vein 1 foot in width is exposed by a small pit. It has a strike of N. 22° E. and is nearly vertical. The quartz contains coarse cubical crystals of pyrite similar to those found in the other gold-bearing veins in this granite area. Between this point and the McGloam vein numerous openings have been made, but they are not in perfect alignment and the veins which were prospected seem to have different courses. The greatest amount of development work was done at a point where the Gold Hill vein, running northeast-southwest, is said to be intersected by the "Cross" vein. There are several shafts and pits now caved along the course of the latter vein, which has a strike of N. 30° W., and is said to dip southwest at an angle of about 35°. This work was done many years ago and little is now known concerning these veins. A piece of quartz containing small prisms of black tourmaline was picked up near the outcrop of the "Cross" vein.

The Page Mine.

The Page mine is located in Fluvanna County on Long Island Creek a mile west of Wilmington. The veins on this property were first mined in 1856 and an 8-stamp mill was built to crush the ores.^a According to Credner the ore was derived from 2 quartz veins, carrying fine-grained galena and gold, which were opened by several tunnels and shafts.^b The mill was in ruins at the time of his visit in 1865. It is reported that prospecting was renewed about 1895, but no mining seems to have been done.

When the property was visited by the writer in 1911 the only accessible opening was a tunnel about 20 feet long which ran under the hill on the west side of the creek. The country rock exposed in the tunnel is a partly decomposed slate but no vein could be seen. Most of the work was done on the east side of the creek where there is an old caved tunnel, and on the hill above it several pits and open cuts. No rock was exposed on this side of the creek, but on the tunnel dump large pieces of vein quartz were found and some of them contained inclusions of chloritic slate, and narrow, irregular veinlets of calcite.

^aNitze, H. B. C., and Wilkins, H. A. J., *Gold Mining in North Carolina and Adjacent Appalachian Regions*, Bull. 10, N. C. Geol. Survey, 1897, p. 75.

^bCredner, H., *Report of Explorations on the Gold Fields of Virginia and North Carolina*, Amer. Jour. Mng., 1869, vol. vii, pp. 42-43.

The gold-bearing gravels along Long Island Creek and some of its tributary branches have been worked, and gold nuggets worth \$20 to \$25 were found on one of the properties a short distance up the creek from the Page mine.^a Placer mining is said to have been carried on as late as 1865.

About $1\frac{1}{2}$ miles up stream from the Page mine there are several openings and a tunnel 100 to 200 feet in length which are said to have been made by Commodore Stockton. Credner states that a series of lenticular quartz concretions were exposed by an incline on top of the hill. The ore was a very hard, sandy quartz, carrying free gold in minute particles. Another quartz vein, nearly 60 feet wide, was exposed by prospecting pits but the ore was very poor.^b

On several properties lying $1\frac{1}{2}$ to 2 miles north of Wilmington a little gold has been found in the placer gravels along the branches, and some quartz veins in that vicinity have been prospected by openings now caved, but all of the work seems to have been very superficial.

The Snead Mine.

Location.—The Snead mine is situated in Fluvanna County, 1 mile north of Fork Union, and is about 3 miles northeast of Fork Union station on the Virginia Air Line Railway.

History.—According to Credner the mine was first opened in 1838 and worked for nine months, during which time it yielded \$6,000.^c The ore was treated in a primitive stamp mill operated by water-power, and much of the gold is said to have been lost in the tailings. Hamilton states that the mine was worked until 1850.^d The vein was opened by a shaft 25 feet deep, several open cuts along the outcrop, and a tunnel. An attempt to reopen the mine was made after the close of the war, and in 1881 the chlorination process of extraction was tried.^e No work has been carried on for many years and the old workings are caved and inaccessible.

Geology.—The vein is located very close to the contact between the sedimentary rocks and the granite. On the west side of the vein near the

^aCredner, H., Op. cit.

^bCredner, H., Op. cit.

^cCredner, H., Op. cit., p. 58.

^dHamilton, J. R., The Natural Mineral Wealth of Virginia, *Harper's Magazine*, 1865, vol. xxxii, pp. 32-42.

^eHotchkiss, Jed., The Tellurium Mine and Virginia Gold Mining, The Virginias, 1881, vol. ii, p. 85.

branch that flows through the property, knotted schists are exposed that are identical with those in the bluffs at New Canton. The rock is bluish-gray, fine-grained, and contains pseudophenocrysts of garnet and biotite 1 to 1.5 mm. in diameter.

The granite on the east side of the vein is a medium-grained gneissic rock composed for the most part of feldspar and quartz, white to light gray in color, with large black blotches of biotite in small flakes. Under the microscope the soda-lime feldspars (oligoclase) are seen to be dominant over the potash feldspars (chiefly orthoclase). Some micropertthite is present. Quartz occurs in irregular grains showing slight optical distortion and contains fluid-filled cavities, zircon, and rutile needles. The biotite is greenish-brown in color and shows strong absorption. Tourmaline occurs in occasional light brown prisms. Much carbonate, a little chlorite, and epidote are present as secondary minerals.

The vein is 3 to 6 feet wide and runs in a northeast-southwest direction, the dip being about 65° toward the east. Credner states that the vein consists of hard white quartz, "containing sulphurets of iron, copper, lead, and zinc, and also oxide of iron, phosphate of lead, carbonate of copper and free gold."^a Hamilton mentions the presence of argentiferous galena.

The Hughes Mine.

Location.—The Hughes mine comprises a tract of 275 acres located in Fluvanna County on the Virginia Air Line Railway about 2 miles northeast of Fork Union station and $2\frac{1}{2}$ miles southwest of Carysbrook.

History.—This mine was first opened in 1836, but for many years it changed hands frequently and very little development work was done. The last period of operation began about 1895 and continued until the spring of 1906, since which time the mine has remained idle. During this period the mine was developed by the Hughes' Gold Mining and Milling Company to a depth of 115 feet, and an elaborate plant installed to treat the ore.

Equipment.—The surface equipment consisted of a double cylinder steam hoist at each of the 2 shafts, a boiler house, mill, and cyanide plant. The mill building contained 2 batteries of 5 stamps each, amalgamated copper plates, and 4 Frue concentrators. The concentrates which carried 60 per cent. of the values were roasted and the gold extracted by treatment with cyanide solutions, while the tailings from the stamp mill were cyanided raw. The extraction is said to have been over 90 per cent. and the cost

^aCredner, H., Op. cit.

of mining and milling a little over \$4.00 per ton. At present the mill is partly dismantled and some of the machinery has been removed.

Underground development and description of veins.—According to Mr. Bugbee, who was general manager for the Hughes Gold Mining and Milling Company, the underground development work has been limited to 3 veins, two of which strike in a northeast-southwest direction parallel to the country rock, while the third running in an east-west direction cuts across the rock formations and intersects one of the other veins. The figures given below were taken from a prospectus issued by the Hughes Gold Mining and Milling Company in 1905.

Shaft No. 1 was sunk to a depth of 40 feet on the larger vein, a level was driven from the bottom of the shaft 140 feet southwest along the vein, and more than 50 feet of ore above this level has been stoped and milled. A mill run on 585 tons of this ore is said to have given a gross value of \$9.00 per ton. The vein has been proved by surface pits for 1,500 feet along the strike and has an average width of $2\frac{1}{2}$ feet.

Shaft No. 2 was sunk to a depth of 110 feet on a second vein about 800 feet southwest of the first, and levels were driven at depths of 60 and 110 feet, respectively. From these levels cross-cuts were driven to reach the third vein 128 feet from the shaft. The second vein has been stoped out from the 60-foot level to the surface. It averaged $1\frac{1}{2}$ feet in thickness between the extremes of 1 and 3 feet, and the average value is given at \$20.00 per ton. The third vein, which has been developed for 230 feet along its strike, varies from 1 to 4 feet in width, averaging 2 feet, and is said to be worth \$13.00 per ton. In addition to the veins mentioned above 4 other veins have been prospected by surface pits and found to contain good values in gold.

Geology of veins and country rock.—At the time this property was visited the underground workings were filled with water and therefore inaccessible, so that it was not possible to examine the veins and wall rock in place. The ore found on the surface is chiefly vein quartz, varying from coarsely crystalline to saccharoidal in texture, and in places it contains much pyrite. Fine flakes of light green chlorite are frequently present in the quartz chiefly along fractures, and chloritic schist containing pyrite was found attached to some of the ore.

The wall rock, as indicated by material found on the shaft dumps, is a greenstone schist derived from an igneous rock, probably a diorite porphyry. In the hand specimen it varies from light to dark green and contains eyes of light blue opalescent quartz, ranging up to 0.5 cm. and

over in diameter. In thin section (Spec. 36)^a the large quartz eyes show optical distortion and some granulation. Rutile needles are occasionally present as inclusions. The ground-mass is composed of soda-lime feldspars, quartz, chlorite, epidote, zoisite, sericite, and a little titanite. The minerals show the effects of mashing, and the feldspars are extensively altered to saussurite and chlorite.

With the exception of the veins belonging to the Gold Hill system, this is the only mine in the district where gold-bearing veins have been found in rock of igneous origin. A short distance west of the veins ferruginous quartzites occur which are similar to those found interbedded with the schists in many localities throughout the area. At several places on the property pieces of almost pure magnetic iron ore are present on the surface, and some specimens^b were seen which have the appearance of a hematite breccia recemented with magnetite and hematite. The magnetite occurs in masses that are composed of small grains and octahedral crystals ranging up to 2 mm. in diameter.

MINES IN BUCKINGHAM COUNTY.

The London and Virginia Mine.

Location.—The London and Virginia mine, or London mine as it is sometimes called, is located about a mile north of Dillwyn, a station on the Buckingham Branch of the Chesapeake and Ohio Railway. It joins the property of the Buckingham mine on the southwest.

History.—This property was first known as the Eldridge mine, and it was worked for a number of years by Mr. Eldridge before being sold to the London and Virginia Gold and Copper Mining Company, which was formed in London and incorporated in Virginia in 1853.^c

At first most of the ore was derived from open cuts, which were carried to a depth of 20 to 40 feet, and extended for a distance of 150 yards along the outcrop. Later, shafts were sunk proving the vein to a depth of at least 150 feet, and underground mining was extensively carried on. Operations were being conducted at the same time on the adjoining property, known as the Buckingham mine, and the two mines were connected underground by a continuous drive along the vein.

The mill used by Mr. Eldridge to pulverize the ores was located some distance north of the mine and operated by water-power. This mill was

^aThis thin section was made from a specimen collected by Dr. J. S. Grasty.

^bSpecimens collected by the State Geologist, Dr. Thomas L. Watson.

^cWhitney, J. D., *The Metallic Wealth of the United States*, Philadelphia, 1854, p. 128.

in operation for about 15 years, and Mr. Partz, in 1854, stated that there were at least 200,000 bushels of tailings lying on the ground, which could be advantageously worked over a second time.^a Later a mill was built a few hundred yards southeast of the vein, and the pile of tailings, which remains to this day, is mute evidence of an industry long since suspended. The property was closed down 5 or 6 years before the Civil War, and since that date active mining has not been resumed, but it is said that the old piles of tailings have been reworked at a profit, and \$10,000 extracted from them.

Descriptive geology.—The London and Virginia “vein,” or “bed” as it has been variously called, has been opened up for practically the entire distance across the adjoining properties of the London and Virginia and the Buckingham mines, and there are numerous shafts and pits located along its line of strike for a distance of several miles. Since the greatest amount of development work has been done on the two properties above mentioned, and since the character of the ore and the structural relations of the enclosing country rocks are essentially identical wherever they have been observed; a single detailed description will suffice for both the London and Virginia and the Buckingham mines, and in the case of other properties located along the same vein only the variations from this description will be noted.

The London and Virginia vein is situated in a series of fine-grained schists and schistose quartzites, all of which are probably sedimentary in origin. The formation has an average strike of N. 40° E. and dips at a steep angle toward the southeast, in places being practically vertical. While there are few outcrops in the vicinity of the mines, the material on the dumps and the rocks exposed in the open cuts, which are almost continuous along the outcrop, together with the descriptions of the mines by Ansted, Henwood, and others, who examined them when they were accessible, furnish sufficient facts to make possible the drawing of general conclusions in regard to the character of the ore, and the relation of the ore deposit to the surrounding rocks.

Henwood states that “a rather fissile and somewhat contorted clay-slate, of homogeneous texture and leaden hue—the lowest rock observed in the neighborhood—is succeeded by a narrow band of whitish quartzose mica-slate, frequently interspersed with talc [probably sericite]; the auriferous deposit which succeeds is overlaid by thin lamellar greenish-white chloritic talc-slate [sericite-schist] now and then flecked with mica.”^b

^aPartz, A., *Examinations and Explorations on the Gold-Bearing Belts of the Atlantic States*, Mining Magazine, 1854, vol. ii, p. 380.

^bHenwood, W. J., *Observations on Metalliferous Deposits*, Trans. Royal Geol. Soc. of Cornwall, 1871, vol. viii, p. 376.



Fig. 17.—Sketch of map showing surface geology and location of mines and prospects along the strike of the London and Virginia vein, in the vicinity of Dillwyn.

A rock (Spec. 340) probably corresponding to the lead-colored slate mentioned above was found by the writer at the Buckingham mine, on the dump of a small pit which is located on the west side of the road crossing the property, and about 100 yards northeast of the outcrop of the vein. This rock is a chloritic schist varying somewhat in granularity but

usually fine-grained. The dominant type is a dark gray schist in which most of the minerals are too fine for megascopic identification. It is cut by frequent fracture lines along which a little epidotization has taken place. Sericite, quartz, and chlorite can be identified with the aid of a pocket lens, and the rock contains much fine-grained magnetite, a little pyrite, and is closely sprinkled with small pink garnets, less than 0.5 mm. in diameter.

Apparently the same chloritic schist as that just described crosses the road 125 yards northeast of Shepherd's Crossroads. While much weathered at this point the rock does not appear to be more than 50 or 60 yards wide. Northwest of this bed no exposures were found but the residual decay indicates that, for some distance, the country rock is for the most part a light-colored quartz sericite schist.

About 50 yards southeast of the rock described above, and 50 yards northwest from the outcrop of the vein, there is an old shaft or pit, now caved, but the dump contains some comparatively fresh rock (Spec. 341). It is a very fine-grained quartz-sericite schist, pure white in color, which breaks readily along the cleavage planes, exhibiting a bright lustrous surface due to minute flakes of sericite. The rock is cut in two or more directions by closely spaced joints that cut the planes of schistosity at an oblique angle. A few grains of opalescent quartz, 0.75 mm. in diameter, and very fine grains of pyrite are the only minerals that can be distinguished megascopically.

In thin section under the microscope the rock is seen to consist largely of small quartz grains, the spaces between them being filled with a clear colorless mineral without cleavage and having a much lower index of refraction than the quartz (probably albite or orthoclase feldspar). Small flakes of sericite occur, mostly segregated in separate bands. There are also narrow bands or veinlets of quartz, slightly coarser grained than the rest of the rock, and the frequent association of these with pyrite suggests that they may in part be due to the circulation of solutions, rather than to recrystallization without migration of the mineral particles. Gas- and liquid-filled cavities are present in the larger quartz individuals. The pyrite ranges up to 0.2 mm. or over in diameter, but most of it is much finer. A little titanite is present in small grains.

The quartz-sericite schist by decrease of sericite passes into a fine-grained schistose quartzite, which usually carries more or less sericite. In places the change from schist to quartzite is quite sharp, but the fact that the two rocks are contemporaneous and have had a similar origin

can not be doubted. In the vicinity of the vein both the quartzite and schist are heavily impregnated with pyrite.

West of the vein, the rocks in places contain much magnetite. Some of the quartzite carries fine-grained magnetite and hematite, and on the surface, near the outcrop of the vein, pieces of biotite schist were found which contained numerous well-formed octahedra of magnetite. This rock is fine-grained, dark gray to black in color, and is composed for the most part of biotite, quartz, numerous reddish-brown garnets, and, in places, much magnetite in perfect octahedral crystals about 1 mm. in diameter. In the different laminae the proportion of these minerals varies somewhat and a little sericite may also be present. The rock is cut by a number of bands or veinlets of fine-grained quartz, which are usually parallel to the schistosity.

Southeast of Shepherd's Crossroads 150 yards, a fine-grained sericite schist outcrops in the road. It has a strike of N. 40° E. and dips steeply to the southeast. The rock is composed essentially of fine-grained white sericite with little if any quartz, and contains numerous small iron-stained cavities left by the oxidation and removal of pyrite or magnetite. For a distance of several hundred yards southeast of this point, while there are no exposures, much magnetite is concentrated on the surface, and it has probably weathered out from magnetite-bearing schists essentially similar to those already mentioned.

About 100 yards northwest of the vein, where it outcrops at the Buckingham mine, a diabase dike about 75 feet wide crosses the road in a northeast-southwest direction, but could not be traced for any great distance along the strike. A short distance west of the road a small pit furnishes exposures of the fresh rock. It is a coarse-grained, olivine-bearing rock, with marked ophitic texture. The feldspars are 3 to 4 mm. long and twinning is easily detected with the naked eye. It is unlikely that this rock has in any way influenced the ore deposits.

Description of vein.—Since most of the vein exposures have been rendered inaccessible through the caving of old workings it is not now possible to examine the ore-body in detail, but Henwood gives the following description:

“The metalliferous bed, conforming to the dissimilar flexures of the rocks on opposite sides, varies in width from 3 to 20 feet on the northeast, but 4 to 5 only toward the southwest. The northeastern portion consists, near the surface, of granular, massive, and cellular quartz; sometimes embedded in, but frequently mingled with, earthy brown iron ore. Traces of galena occur at intervals; and small drusy cavities often afford crystals

of the phosphate of lead and of selenite. The quartzose parts contain bodies of friable iron pyrites; of which the most deeply seated are the largest and most numerous. These . . . enclose isolated masses of copper-pyrites; invested occasionally with copper-glance, but more generally with earthy black copper ore.^a The southwestern portions include many unconnected, angular blocks of slate; of all which the composition resemble, and the planes of structure conform to, the compositions and structures of the rocks in their respective neighborhoods. Except in this particular, and that massive quartz is more abundant, the southwestern parts differ but little from the northeastern. . . . The earthy brown iron ore and the quartz are slightly auriferous when separate; but when united in certain manners and proportions—more easily recognized than described—they frequently enclose small nuggets, thin plates, and crystalline grains, united by threads of gold; which constitute from 0.0000056 to 0.0000070 of the ore extracted.”^b

According to Partz the oxidized or “soft ores” extended to a depth of 20 to 40 feet “where the slate became hard and solid on account of the undecomposed auriferous pyrites in it”;^c and Ansted states that “about 80 feet down from the surface threads of copper ore were found consisting of copper pyrites mingled with iron pyrites which forms the staple.”^d

The sides of the old open cuts from which the ore was taken frequently furnish exposures of dark iron-stained quartzite, usually containing small cavities due to the removal of pyrite. At the Buckingham mine a large mass of this quartzite remains standing in the center of the opening, ore having been removed from either side, and the walls of the cut are of the same material. Where the surface has not been disturbed there are in places outcrops of quartzite in line of strike with the old workings.

The ore found on the dumps and in the vicinity of the mine which came from the deeper workings is mostly fine-grained, white quartzite with more or less disseminated pyrite. White quartz-sericite schist similarly impregnated with pyrite also occurs, but does not appear to be as plentiful at the Buckingham and London and Virginia mines, as at some other localities along the strike of the vein.

^aThe following note is given by Henwood on page 376 of the publication previously cited:

“This ore afforded 0.230000 its weight of copper
 0.001142 its weight of silver
 0.000060 its weight of gold

Johnson and Matthey, *Prospectus of the London and Virginia Company*, p. 2.”

^bHenwood, W. J., *Op. cit.*, pp. 376 and 379.

^cPartz, A., *Op. cit.*, p. 379.

^dAnsted, D. T., *The Alleghanies and the Gold District of Eastern Virginia in Scenery*, Science and Art, London, 1854, p. 287.

A specimen (342) found on the dump at the Buckingham mine shows the quartzite in contact with the quartz-sericite schist. The quartzite is a white, fine-grained, even-granular rock, impregnated with fine crystals of pyrite; and a little sericite in minute flakes can be distinguished on fracture surfaces approximately parallel to the schistosity. The schist is composed of the same minerals as the quartzite, the difference being in their relative proportions; sericite is very prominent, though in this specimen quartz is probably the dominant mineral, and pyrite is more abundant than in the quartzite. The contact between the two rock types while slightly irregular is quite sharp, and makes an angle of about 40° with the schistosity of the rock. The pyrite is uniformly disseminated, except that it is more plentiful in the schist than in the quartzite, making up perhaps 10 or 15 per cent. of the former and not more than 4 or 5 per cent. of the latter.

In thin section under the microscope the quartzite is seen to be composed of small clear, interlocking grains of quartz showing no optical distortion, idiomorphic crystals of pyrite ranging from dust-like particles up to crystals 1 mm. in diameter, and a few flakes of sericite. Occasional scattered crystals of orthoclase and acid plagioclase may be observed, and in places interstitial space between the quartz grains contains a light brown or colorless to cloudy mineral which is isotropic, and has a low index of refraction. It is probably some variety of opal. The quartzite has undoubtedly undergone extensive recrystallization, and the pyrite which impregnates the rock is probably secondary, replacing some of the quartz.

Only a very little massive vein quartz can be seen on the dumps, but several pieces of quartzite were found cut by small veinlets of massive quartz, ranging up to several inches in thickness. One specimen (343) shows a vein of massive quartz, 2 to 4 inches wide, which contains feldspar, nearly white in color with a slightly pinkish cast, and difficult to distinguish at a glance from the quartz. The feldspars occur partly in single individuals 1 to 2 mm. in diameter and partly in clusters having an area of 2 cm. or more. Occasionally coarse multiple twinning can be distinguished with the naked eye. The quartzite and schist in contact with these veinlets are heavily impregnated with pyrite, but the vein quartz contains comparatively little of this mineral.

In addition to the minerals mentioned in the above descriptions, several others have been reported by various writers. Partz states that "in one pit we found several specimens of fibrous (asbestiform) actinolite. . . . Specular ore of a great variety, in form and color, is frequently met with.

There were shown to us pretty specimens of heavy spar (sulphate of barytes) and talcite, taken also from these mines."^a

Genth found a mineral associated with quartz and auriferous pyrite in ore from the London and Virginia mine which in composition corresponds to tennantite, the analysis being closely similar to that of a specimen from the Jucud mines, given by Dana.^b The description of the mineral as given by Genth is quoted below.

"In granular masses; lustre metallic; color between iron-black and lead-gray; streak iron-black; opaque; H. = 4. Very brittle; fracture uneven—subconchoidal.

"B. B. in an open tube disengages sulphurous acid; and gives a sublimate of arsenious acid. On charcoal it emits fumes of an alliaceous odor, and fuses with intumescence to an iron-black, slightly magnetic globule, covering the charcoal with white incrustations. With fluxes it gives the reactions of copper and iron."

A preliminary analysis, made by dissolving the mineral in aqua regia, gave Mr. Wm. J. Taylor the following results:^c

	Per cent.
Copper	40.64
Silver	0.42
Gold	trace
Zinc	3.39
Iron	4.24
Antimony	5.10
Arsenic	16.99
Sulphur	28.46
Quartz	1.24

The Buckingham Mine.

Location.—The Buckingham mine is situated three-quarters of a mile northwest of Dillwyn, and on the northeast it joins the property of the London and Virginia, both being located on the same vein.

History.—In some of the earliest descriptions of this property it is referred to as the Wiseman mine. The Buckingham Gold Mining Company was organized to operate the property in 1853, and proceeded to develop the mine on a larger scale.^d The earliest work was limited to open cut mining and the surface openings were carried to a depth of 20 to 40 feet. Later 2 shafts were sunk and levels were driven to some extent along the

^aPartz, A., *Op. cit.*, p. 379.

^bDana, E. S., *A System of Mineralogy*, 6th ed., New York, 1892, p. 140.

^cGenth, F. A., *Contributions to Mineralogy*, Amer. Jour. Sci., 2d ser., 1855, vol. xix, pp. 18-19.

^dWhitney, J. D., *The Metallic Wealth of the United States*, Philadelphia, 1854, p. 128.

vein, connecting through with the underground workings of the London and Virginia mine. The deepest shaft is said to have reached 180 feet, but practically all the ore mined came from the upper portions of the vein. It seems probable that two or more mills have been operated on the property, but the principal mill was located near the branch some distance northeast of the mine. The pile of tailings still in existence indicates that much ore was milled here. Austin writing in 1854 states that an average of 20 tons of ore were being crushed daily, yielding 130 dwt. of gold per day, and that during the previous year 1,500 ounces of gold were obtained from the mine. Mining operations ceased several years before the outbreak of the Civil War and have not been resumed since that date. At present the shafts and underground workings are all caved, while the mills were destroyed years ago.

One of the most noticeable features both at the Buckingham and the London and Virginia mines is the absence of large dumps of waste rock. Practically all the material taken from the mines appears to have been put through the mills.

Geology of the ore-body.—As the character of the ore and the geology of the deposit have already been referred to in describing the London and Virginia mine (see pp. 184-190) they will not be repeated here.

The Williams Mine.

Location.—The Williams mine is located at Shepherd's Crossroads about a mile northwest of Dillwyn. It is less than three-quarters of a mile southwest of the principal workings at the Buckingham mine, and lies directly on the same line of strike (see map, p. 185).

Description.—There are several old prospect pits in this vicinity and recently a shaft has been sunk to a depth of perhaps 50 feet. The dump is covered with white quartz-sericite schist impregnated with pyrite and is similar to that at the Buckingham mine already described. Only a very few small fragments of vein quartz are to be seen, indicating the presence of occasional veinlets, mostly less than an inch in thickness. Pieces of this quartz sometimes contain a little pyrite, chiefly along their edges. The recent work is said to have been done with the hope of developing a pyrite mine. Some of the material on the dump carries as high as 80 or 85 per cent. pyrite. A thin section of this high-grade ore (Spec. 344) when examined under the microscope was found to consist of more or less idiomorphic crystals of pyrite, sericite, a few small grains of titanite, and little or no quartz. The pyrite seems to have replaced quartz in the sericite

schist in preference to the other minerals, chiefly sericite, the latter being affected little if at all.

Passing southwest along the strike of the London and Virginia vein, old prospect pits, trenches, and a few shafts are found at short intervals for a distance of 10 or more miles, until the Bondurant mine is reached a short distance southwest of Andersonville. Most of this work was done over 50 years ago, and to-day the dumps are for the most part reduced to soil and overgrown with trees and bushes, so that there is very little to indicate the character of the material that was removed from the openings. The few written records of this early work confirm the data collected in the field, and indicate that the bed of quartzite, which where mineralized forms the greater part of the ore-body at the London and Virginia and Buckingham mines, is practically continuous throughout most of this distance. The quartzite varies somewhat in width and degree of mineralization, but is remarkably uniform in texture and appearance wherever observed. The outcrops are usually stained with iron and the rock more or less porous from the oxidation of pyrite, but in most cases the sulphides could not have been so abundant as in the vicinity of the London and Virginia, and Buckingham mines. While gold is reported to have been found at many of these places, it is improbable that the values anywhere along this southern extension of the vein approach those obtained from the ores at the London and Virginia, and Buckingham, when these mines were being worked. At several of these properties surface washing has been attempted, but with little success, and no underground mining has been carried on.

The Bondurant Mine.

Location.—The Bondurant mine is located about a mile southwest of Andersonville and about 10 miles from Dillwyn.

History.—Placer mining is said to have been conducted on this property as early as 1836, and some of the hillsides as well as the branches were washed for gold. A few years later it was leased from the owner, Mr. Bondurant, by Major Miller, who built a small stamp mill on the branch flowing through the property and worked a vein that outcrops on the hill about 400 feet to the south. A royalty of a tenth of the gold recovered was paid to the owner, and during the period of 10 months in which mining was carried on, he is said to have received \$240. Credner visited the property in 1865 and writes that "two parallel veins, 30 feet distant from each other, have been opened by excavations 20 to 25 feet deep, and by two shafts, 35 and 45 feet deep, respectively. One of these veins is two

feet wide and the other four and a half feet. They stand nearly vertical, cross the property for three-quarters of a mile, and carry sandy quartz with much oxide of iron and free gold. The ores were crushed in a stamp mill and amalgamated in arrastras; but tailings only now mark the place where these works stood."^a

About 1875 a small stamp mill was operated on the property for a short time, with what results is not known. In 1901, a tunnel starting near the creek was driven southeast for a distance of 410 feet, connecting with three shafts having depths of 30, 40, and 71 feet, respectively, and from a point near its extremity a drive was opened for 96 feet southwest along a vein. Mr. Moore, who had charge of the work at the time, states that 5 parallel veins were encountered in the tunnel, the largest being 31 feet thick while the others ranged from 3 to 8 feet, and that another vein was located by a test pit on the opposite side of the creek. He says that assays were obtained running as high as \$65 per ton, the veins averaging \$4.50 per ton in gold.

Descriptive geology.—The few exposures observed in the vicinity of the Bondurant mine indicate that the country rocks are similar to those at the mines near Dillwyn, which have already been described in detail on pages 184-187. Quartzite, frequently containing magnetite and specular hematite, is the chief rock found on the surface. When the property was visited by the writer in 1911 the greater part of the tunnel had been rendered inaccessible through caving, but the dump afforded much information concerning the character of the rocks.

The so-called "veins" appear to be beds of quartzite, more or less mineralized and cut by occasional veinlets or stringers of massive crystalline quartz, which frequently contain large crystals of muscovite. A specimen (312) of the quartzite cut by small lenses and stringers of vein quartz is shown in fig. 18. The quartzite is white when fresh, fine-grained, even-granular, and slightly schistose, the schistosity being parallel to the bedding. Looking at a piece that has been fractured across the schistosity, the rock appears to consist entirely of quartz with a little fine-grained pyrite, but on a fracture parallel to the schistosity, much white, fine, scaly sericite is visible. Lenticular eyes and stringers of vein quartz occur parallel to the bedding and also cut directly across, as shown in fig. 18. Fine-grained pyrite, much of which is in such small particles as to be almost invisible to the naked eye, is disseminated through the quartzite,

^aCredner, H., Report of Explorations on the Gold Fields of Virginia and North Carolina, Amer. Jour. Mng., 1869, vol. vii, p. 72.

being somewhat more abundant along the principal bedding planes and in close proximity to the veinlets, but the impregnation with sulphides does not appear to be nearly so extensive here as at the London and Virginia, and Buckingham mines.

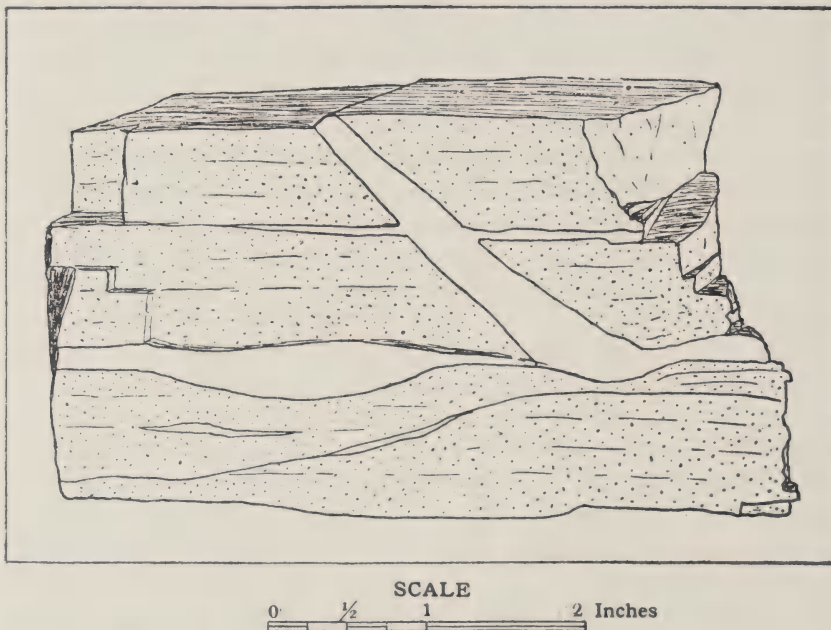


Fig. 18.—Sketch of specimen showing quartz veinlets cutting across bedding and schistosity of quartzite, Bondurant Mine.

The quartzite is interbedded with a fine-grained quartz-sericite schist, containing lenticular eyes of light blue opalescent quartz ranging up to 0.75 cm. in length. The folia of the schist are wrapped around these eyes giving a knotted or bird's-eye maple like structure to the rock. Pieces of quartzite were found on the dump with the schist still adhering, and the contact between the two is not perfectly sharp but shows some gradation. Another piece of schist contained interbedded layers of quartzite that were only a half to an inch in thickness.

Some of the rock (Spec. 366) found on the dump is intermediate in composition between the typical quartz-sericite schist of the district and the quartzite. It is a fine-grained, close-textured, light gray schist, with a faintly greenish tinge due to microscopic flakes of chlorite and sericite. In

thin section under the microscope the minerals present, in the order of relative abundance, are quartz, pyrite in cubical crystals ranging up to about 0.5 mm. in diameter, small flakes of sericite and chlorite, a few grains of magnetite, and occasional inclusions of zircon and titanite.

A little diabase (Spec. 368) was found on the dump. It is a fine-grained, close-textured, dark gray rock in which no olivine could be identified with the aid of a pocket lens.

The Anderson Mine.

Location.—The Anderson mine, located about a quarter of a mile south of Andersonville postoffice, lies just northeast of the Bondurant mine.

Description.—The big bed of quartzite opened on the Bondurant can also be traced across this property by outcrops and old pits scattered along its line of strike. A shaft is said to have been sunk on the property to a depth of 50 feet, connecting with a tunnel 70 yards long, but both had caved before 1865, and to-day there is little trace of their former existence. A little placer washing was done in the branches soon after gold was discovered, but that is the extent of the mining operations conducted on this property.

The Flood Mine.

Location.—The Flood mine lies southwest of the Bondurant and is separated from it by Willis River.

Description.—This property was formerly known as James Anderson's mine, and a little placer washing in the branches is said to have been carried on soon after gold was discovered in the district, but with what success is not known. A shaft and tunnel were opened prior to the Civil War, but they have long since caved, and nothing is now known as to the character of the vein exposed.

The Gilliam Mine.

The Gilliam mine adjoins the Flood mine and is the most southwesterly opening on the bed of quartzite, apparently continuous for so many miles northeast of the property. Whether it stretches yet further to the southwest is not known. According to Credner, who examined the property in 1865, when the "vein" was exposed by 7 cuts and a shaft 20 feet deep, the "vein" is standing vertical and has thinned to a width of only 4 feet. He states that the outcrop consists of brown oxide of iron with only a little quartz, which indicates that the quartzite is probably more heavily impregnated with pyrite than at the Bondurant mine.

The Burnett Mine.

Location.—The Burnett mine is situated on the London and Virginia vein about three-quarters of a mile northeast of the London and Virginia mine and $1\frac{1}{4}$ miles north of Dillwyn.

History.—This property was formerly known as the Staples mine, and, when visited by Credner in 1865, there was a shaft 54 feet deep exposing "a multitude of lenticular quartz concretions in talcose [quartz-sericite] slate of bluish color which contain oxide of iron and free gold. The bushel, or one hundred pounds of this ore, is worth one dollar."^a The London and Virginia vein was not opened on this property until 1881, when the Burnett Mining and Milling Co. began development work. A shaft was sunk to a depth of 80 or 90 feet and a short tunnel driven from the south-west along the vein to connect with the shaft. There was another shaft a few yards northeast and a number of pits, all of which are now caved. The mine was worked during 1881, 1882, and a part of 1883, but has since been idle.

A mill was located 300 to 400 yards west of the mine on the west side of a large branch. It consisted of 3 batteries of 4 stamps each. The mortar boxes were of cast-iron, while the stamps had square wooden stems with cast-iron shoes. The mill burned some years ago, but the charred stumps of the stems can still be seen standing in the batteries. There is quite a large tailings pile below the mill, but it is said that most of the ore milled was hauled from the London and Virginia mine.

Descriptive geology.—The country rock, as indicated by the dump and by rock in place in the shaft, is a white, lustrous quartz-sericite schist impregnated with fine-grained pyrite, similar in every way to the rock occurring on the northwest side of the vein at the Buckingham mine. The "vein," exposed in the shaft, is a bed of quartzite 3 to 4 feet thick, having an approximate strike of N. 45° E. and a dip that is vertical or steeply inclined toward the southeast. The quartzite is very schistose and contains considerable sericite. In most places near the surface it is colored dark brown by the oxidation of pyrite, which has left small cavities in the rock. This ore is similar to that at the London and Virginia and the vein has been traced from one mine to the other by means of surface cuts, outcrops, and float.

^aCredner, H., Report of Explorations on the Gold Fields of Virginia and North Carolina, Amer. Jour. Mng., 1869, vol. vii, p. 72.

The Hobson Tract.

The Hobson tract, formerly known as the Morton mine, lies between the Burnett mine and the London and Virginia. According to Credner a 40-foot shaft was sunk on the London and Virginia vein which here attains a width of 10 to 15 feet and exhibits the characteristic appearance of the quartzite where the pyrite has been thoroughly oxidized. The vein has never been worked to any extent on this property.

The Morton Mine.

Location.—The Morton mine is located half a mile west of Johnson, a station on the Buckingham Branch of the Chesapeake and Ohio Railway, and is about 7 miles northeast of the London and Virginia mine.

History.—This property was formerly known as the Hobson mine, and according to Pollard it was the first mine opened in the county. Surface washing was carried on in the early days. When the property was visited by Credner in 1865 three parallel veins had been opened to a depth of 25 or 30 feet. He states that they are from 3 to 10 and in some places even 20 feet wide, and consist of granular massive quartz carrying oxide of iron and free gold. One of these veins is said to be the continuation of the London and Virginia vein.^a In 1906, two shafts, the deepest probably not more than 30 feet, were sunk on the property, but there is nothing on the dumps to indicate that either one struck a vein. When the writer visited the property in 1911 all openings had caved except the last mentioned shafts. There is an old dam on the small branch west of the shafts, and on the opposite side the ruins of a building, said to have been used in washing gold. A little water-worn gravel was found around the building.

Geology.—The mine is situated in an area of quartzites and schists, lying just west of the Arvonian slate belt and in line of strike with the London and Virginia mine which is 7 miles southwest. The two shafts sunk in 1906 were put down in a quartz porphyry, fresh specimens of which were exposed on the dump.

The rock (Spec. 360) is light gray to nearly white, slightly schistose, and is composed for the most part of feldspar and quartz. Occasional eyes of light blue to colorless, opalescent quartz, ranging up to 0.75 cm. in diameter, are distributed through the rock. A few grains of ilmenite and pyrite, and along cleavage planes a little sericite and chlorite make up the remaining constituents visible to the naked eye. In thin section

^aCredner, H., Report of Explorations on the Gold Fields of Virginia and North Carolina, Amer. Jour. Mng., 1869, vol. vii, p. 58.

under the microscope, the large quartz eyes are seen to be full of small zircon crystals, exceedingly minute rutile needles, and gas and liquid inclusions. The potash feldspars (orthoclase and microcline) are dominant over the soda-lime feldspar (albite-oligoclase or oligoclase) and orthoclase is more abundant than microcline. There is also much micropertthite present in the slide. The minerals show no granulation and little if any optical distortion, but the feldspars show some alteration to sericite, and to calcite, while the ilmenite is partly altered to leucoxene.

Between the Morton and the London and Virginia mine, and along the same general strike, a number of properties have been prospected by means of pits and surface cuts, but no regular mining, aside from placer washing, has been conducted on any of them.

A property, formerly known as the Rough and Ready mine, adjoins the Morton mine on the southwest. At some time before the outbreak of the Civil War a shaft was sunk on a quartz vein carrying pyrite, and, in 1879, a pit opened on the property is said to have exposed a vein 6 feet in width which showed gold on panning.

On the Duncan tract, about $1\frac{1}{2}$ miles west of Alpha, the gravel deposits along the branches were formerly worked for gold and a vein on the property was prospected a little but never worked.

Lying between the London and Virginia and the Duncan properties is a tract of land, which at different times has been known as Le Seur's or Apperson's mine, and on it a vein is said to have been explored and some ore raised before the war. Later prospecting was renewed, and in 1882 Campbell writes that 3 veins were exposed. The first, measuring 10 to 15 feet in width, consisted of a porous siliceous mass containing disseminated particles of gold. The second vein, about half a mile east of the first, was of whiter quartz but had not been well exposed. The third vein, which was still farther to the east, consisted of gold-bearing quartz disseminated in hard schistose rock like that at the Morrow mine.^a

The Morrow Mine.

Location.—The Morrow mine is located about $3\frac{1}{2}$ miles southwest of Dillwyn and 2 miles east of Enonville.

History.—It was one of the first properties in Virginia on which underground mining was attempted and has had a long and varied history. When Prof. W. B. Rogers wrote his "Report of the Geological Recon-

^aCampbell, J. L., *The Virginia Gold Belt near the Richmond and Alleghany R. R., The Virginias*, 1882, vol. iii, p. 120.

noissance of the State of Virginia, 1835," Booker's mine, as it was then called, was already in active process of development. In its early history the property consisted of 2 separate mines on the same vein within 100 yards of each other, which were worked by W. M. Moseley and Co., and the Garnett Mining Co., respectively; but in 1852 they were consolidated under one management and incorporated under an act of the Virginia Legislature. For several years after this the property was controlled by an English company. In the early writings on geology and mining, the workings were usually referred to as the Garnett and Moseley mines, or the Booker mine, but since about 1880, when it was worked for a few years by the Morrow Mining Co., it has been known as the Morrow mine.

Several mills have been built on the property and much money has been wasted through the installation of expensive machinery, which after little or no use was pulled out to make room for later inventions. While the Garnett and Moseley mines were being worked separately there were two small mills in operation. In 1854, soon after the English company had bought the mine, Mr. Partz^a states that a new mill with 72 stamps was in operation, replacing the 24 stamps that had previously been employed, and that the amalgamation was performed on two sets of shaking tables. When Credner visited the district in 1865 the mines were shut down, but he describes two mills he found on the property; one containing 4 shaking tables, nearly new, and a very large ball-crusher which had not been used; the other with 12 batteries of 3 stamps each, 72 shaking tables, arranged in 2 systems, and Chilian mills.^b In later years, a Howland mill, consisting of a flat circular disk revolving in an iron shell, was used to pulverize the ore, and the sulphides were concentrated on 2 vanners. An attempt was made in 1893-4 to treat the sulphides by the Mears chlorination process, but it is said to have failed because of mechanical defects in the process used, though a satisfactory extraction of the gold was obtained.^c In 1911 there was no mill on the property.

Production.—Because of lack of records it is not possible to state the total amount of gold produced by this property. A prospectus of the Garnet Gold Mining Co., printed in 1852, gives the production of both mines for the previous year as follows:

United States Mint receipts for gold.....	\$25,007.53
Gold on hand and ore reserved as specimens...	1,500.00
Total	\$26,507.53

^aPartz, A., *Examinations and Explorations on the Gold-Bearing Belts of the Atlantic States*, Mng. Mag., 1854, vol. ii, p. 378.

^bCredner, H., *Report of Explorations on the Gold Fields of Virginia and North Carolina*, Amer. Jour. Mng., 1868, vol. vi, p. 393.

^cFroehling and Robertson, *A Hand-Book on the Minerals and Mineral Resources of Virginia*, 1904, p. 48.

Mr. W. J. Henwood gives the amount of gold derived from both mines for the years 1850-2 inclusive.^a

Annual production of gold in pounds Troy.

Year	Garnet mine.	Moseley mine.
1850 .....	.....	97.92
1851	36.75	71.74
1852 (8 months)	20.17	31.19

Over \$60,000 is said to have been recovered from the placer washings near the veins.

Underground development.—Before underground work was resorted to, most of the upper portion of the Booker vein was removed by open-cut surface mining down to a depth of 30 feet, and for a distance of over 400 yards along the outcrop. By 1853, it is said that 5 shafts used for hoisting, ventilation, and pumping had been sunk to an average depth of 100 feet, and connected by drives 350 feet in length. The vein had been proved for over half a mile by 4 or 5 shafts 30 to 50 feet deep, and by as many as 50 surface cuts.^b Later development work extended the underground workings, and a good deal of stoping was done, but none of the shafts seem to have been carried below 115 feet. When the property was visited in the summer of 1911, the openings had partly caved and none of them was accessible.

Descriptive geology.—The Morrow mine is situated in an area of intensely metamorphosed schists and gneisses, which, for the most part, are probably derived from sedimentary rocks. At Tongue Quarter Creek about a mile southwest of the mine there is a large area of fine-grained, dark green, hornblende schists, and 2 miles southwest of the property are the bold outcrops of cyanite schist and quartzite that form Willis Mountain.

In the immediate vicinity of the mine there are few rock exposures, but the old shaft dumps furnish much information concerning the character of the country rock enclosing the ore deposits. These rocks are all schistose and usually show more or less banding; they range from light to dark gray and green in color, are usually garnetiferous, and frequently contain an abundance of calcium-iron carbonate, probably a variety of ferrocalcite. The latter mineral is finely crystalline and light brown in

^aHenwood, W. J., *Observations on Metalliferous Deposits*, Trans. Royal Geol. Soc. of Cornwall, 1871, vol. viii, p. 382.

^bThe Garnet and Moseley Mines, Virginia (Reprinted from a paper by "The Editor," in the *Richmond Enquirer*), Mining Mag., 1853, vol. i, pp. 164-167.

color when fresh, turning to dark brown on weathering; it effervesces very slowly in cold dilute hydrochloric acid, and on heating before the blowpipe becomes only slightly magnetic. Wet tests give heavy precipitates of calcium and iron, but little or no magnesium.

A thin section was made from a light gray, gneissic rock in which the carbonate was particularly plentiful. Megascopically the rock (Spec. 378) shows imperfect banding of the light- and dark-colored minerals; the lighter bands being largely composed of carbonate and quartz, while in the dark ones biotite is a prominent constituent. White mica, pink garnets, and a few small grains of magnetite and pyrite may also be recognized. Under the microscope, carbonate is dominant in the thin section, with quartz, sericite, biotite, soda-lime feldspar (andesine ?), and garnet following in the order named. Some of the quartz shows much optical distortion, but large clear grains of secondary quartz are also present. The feldspars are fresh and clear, and usually show multiple twinning after the albite law. The garnets show no suggestion of crystal form, and are simply granular aggregates, intermixed with the other minerals, principally carbonate.

There is much light gray schist (Spec. 379) on the dumps, in which the principal constituents distinguishable without the aid of the microscope are fine-grained quartz, sericite, scattered flakes of biotite, averaging 1 mm. in diameter, and occasional eyes of opalescent quartz 5 or 6 mm. in diameter.

Another rock type (Spec. 376) occurring on the dumps, is a dark green and reddish-brown gneiss in which most of the minerals (especially mica and garnet) are very largely concentrated in narrow bands or lenses. Megascopically, the following minerals can be distinguished: Biotite, in black flakes 0.5 to 1.5 mm. in diameter, which occur partly in narrow bands, the cleavage of the mica being at varying angles with the schistosity of the rock; garnet, in irregular lenticular masses 1 cm. or more in thickness; fine flakes of sericite and light green chlorite; quartz; much fine-grained magnetite; and occasional feldspars, 1 to 1.5 mm. in diameter.

In thin sections under the microscope, much feldspar can be distinguished, partly a soda-lime feldspar with albite twinning, and partly a clear feldspar with low index of refraction and no twinning (albite or orthoclase). Much of the feldspar and quartz show optical distortion, and in places zonal extinction can be observed. In addition to the minerals already mentioned, much calcite was noted, and occasional fragments of zircon and titanite. Gas- and liquid-filled cavities occur in some of the quartz.

Dark green hornblende is present in part of the schists, and some pieces are heavily loaded with the sulphides, pyrite and pyrrhotite. Some of the pieces of schist and gneiss contain lenses or stringers of quartz and carbonate, usually with a little white mica; and there is a great deal of rock (Spec. 373) on one of the dumps, consisting of dark-colored, fine-grained schists, cut by numerous branching veinlets of quartz and carbonate, with some muscovite and light green chlorite. These veinlets range up to several inches in thickness, and often make up as much as 50 per cent. of the rock mass. This material is very similar to some of the "vein" stuff described by a number of geologists who have examined the underground workings. Thus, Prof. Campbell states that, "the 'vein,' as it is called, in which work was going on [at the time of his visit in 1881 or 1882], is at least 30 feet wide, and is composed of a schistose rock with injected quartz, forming in some places secondary veins and thin sheets, and at other points, apparently dispersed, with its accompanying auriferous pyrites, in the slaty beds of hard rock that make up the main mass of what is taken from the mine."^a

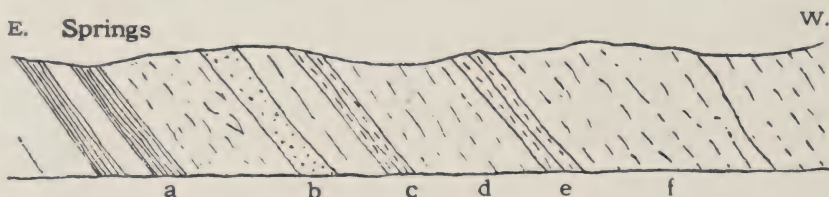


Fig. 19.—Section across the district worked for gold in the Morrow Mine. (After Ansted, *Scenery, Science and Art*, p. 289.) *a*, rotten schists with pipe clay; *b*, steatite; *c*, principal auriferous band called east vein; *d*, hornblendic rock; *e*, upper auriferous band (west vein); *f*, overlying beds.

Prof. Ansted describes the "belt" of rocks in which the ore bodies occur and gives a geological section showing the structural relations of the rocks in their immediate vicinity. (See fig. 19.) His description is as follows:

"The actual breadth of this belt I had no means of exactly ascertaining, but it certainly exceeds 200 yards, and is probably much greater. It is, however, subdivided, including distinct bands of mixed quartz threads and rotten red and yellow or greenish schists (*a*). On these repose bands of talcose or chloritic schist, which pass into an imperfect steatite (*b*), occasionally used as a firestone to line furnaces. All these are on the east or lower side of the series. In the middle, between the two well-marked auriferous bands which next succeed, is a certain thickness of hornblendic greenstone (*d*) hard, and tolerably compact. The eastern auriferous band has been extensively worked at the surface."^b

^aCampbell, J. L., *The Virginia Gold Belt near the Richmond and Alleghany R. R., The Virginias*, 1882, vol. iii, pp. 120-121; *Geology and Mineral Resources of the James River Valley*, New York, 1882, pp. 99-106.

^bAnsted, D. T., *Scenery, Science and Art*, London, 1854, Chap. 3, *The Alleghanies and the Gold District of Eastern Virginia*, pp. 289-290.

Henwood states that the rocks exposed in the mine contain "mica, talc [probably sericite], and chlorite in large but ever-varying proportions," so that one or the other may dominate in laminae only a few inches apart, or even in different portions of the same rock layer.^a

Besides the "principal bed," Henwood mentions four other "auriferous beds," occurring in and immediately northwest of the mines, which "maintain tolerable parallelism; except where they are affected by unequal flexures of the adjoining rock; to the schistose structure of which they strictly conform." They vary from 4 to 18 feet in maximum width, but average much less, and "within short distances some of them divide, dwindle, and die away; occasionally, however, they reappear and again enlarge."^b

The slates beneath the "principal bed" dip northwest at an angle of 40° to 60°, but those above preserve the same inclination to a depth of 60 feet only, and thence downward dip 20° to 30°. As the hanging-wall or northwestern side recedes from the foot-wall, and the "auriferous bed" between them becomes broader, it encloses lengthwise a wedge-shaped mass of slate, which widening downward partakes in some measure of the mineral character of the surrounding "vein-stone," while in structure it coincides with the neighboring rocks.^c

According to Prof. Ansted, "the enclosing rock, which within 20 feet of the surface is hardly to be distinguished from the vein, gradually changes below this point, and within a depth of 10 or 15 feet becomes a hard, compact talcose [probably quartz-sericite] schist, often containing fine garnets, and not infrequently iron pyrites. In this schist, at a small depth, are a multitude of quartz threads, and farther down these threads come together, forming a distinct quartz band, often enclosing portions of the schist. The gold disseminated indifferently near the surface, amongst the quartz, rotten schists and enclosing walls, gradually collects together into threads, usually ranging with the schistose portions within the quartz band. The walls are very distinctly marked, and easily separated, and are found to be no longer auriferous, while the quartz, of which the thickness amounts to 10 feet at a depth of about 100 feet from the surface, seems to increase continually in value."^d

The appearance of the vein is shown in the generalized sketch (fig. 20), which is drawn from pieces of rock found on the dump, and is in accordance with the descriptions of several observers, who have examined the underground workings.

^aHenwood, W. J., *Observations on Metalliferous Deposits*, Trans. Royal Geol. Soc. of Cornwall, 1871, vol. viii, p. 379.

^bIbid., p. 380.

^cIbid., pp. 380-381.

^dAnsted, D. T., *Op. cit.*, p. 290.

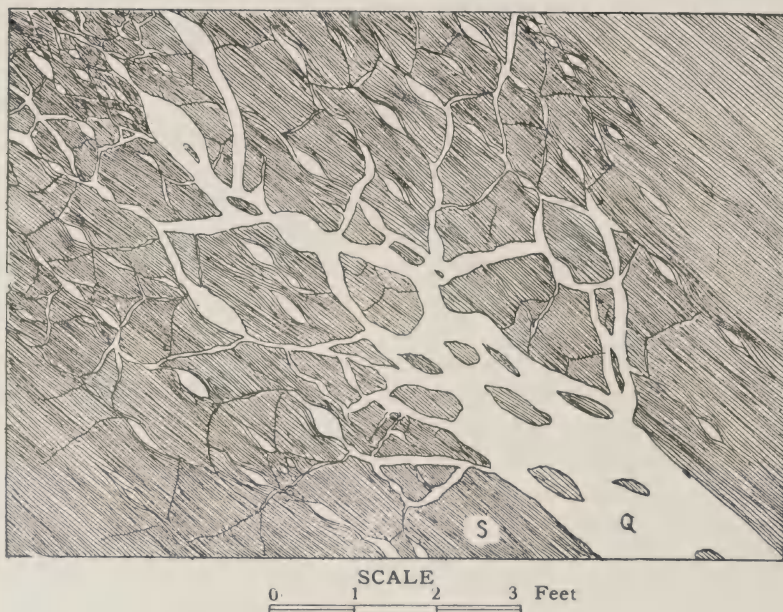


Fig. 20.—Sketch showing reticulated veinlets with inclusions of wall rock at the Morrow Mine. *Q*, quartz; *S*, schist.

Description of ores.—Quartz and schist, varying in relative proportions, always make up the greater part of the ore-body, but Henwood also mentions the presence of small quantities of feldspar scattered throughout, and in the deeper portions calcareous spar, pyrite, and crystals of common garnet. He states that veinlets of quartz, feldspar, and calcareous spar cut the metalliferous beds at intervals irrespective of their slightly foliated structure, which is generally parallel to the cleavage of the adjoining strata. Near the surface all parts of the rock-mass contain particles and grains of gold but at greater depths, in the “principal bed” flakes, granules, nuggets, and threads here and there intertwine the quartz with groups of golden filigree. It is stated that tellurium often accompanies the gold but is never abundant.^a According to Campbell the gold is said to carry a considerable percentage of silver.^b

^aHenwood, W. J., Op. cit., p. 382.

^bCampbell, Op. cit.

Henwood believes that there is a decrease in values with depth, and after calling attention to the gradual decrease in production for the years 1850-52 (see p. 200), during which time approximately the same number of men were employed in extracting the ore, states that, "these results show the proportions of gold to have been larger in the shallower and narrower, than in the deeper, wider, and flatter parts of the principal bed."^a

Selected samples are said to have carried 3 oz. 16 dwts. in gold, but ore from a depth of 90 feet in the Garnett mine yielded an average of 10.1 dwt., and from the Moseley mine an average of 8.1 dwt.^b

Credner says that the gold-bearing beds are cut off by domes and ridges of diorite; but the mines were closed at the time of his visit in 1865, and he does not give his authority for this statement.^c

Placers.—During the early history of the property the placer deposits were much worked, and over \$60,000 is said to have been recovered from the gravels near the veins. Henwood quotes Major Miller as writing that "a nugget of nearly 9 pounds, besides many masses of a few ounces each were mixed with grains of gold in the bed of a rivulet immediately south of the Garnett and Moseley mines."^d

The Seay Mine.

The Seay property adjoins the Morrow mine on the west, lying between it and Enonville, and belongs to the same company.

The placer gravels were washed for gold and several quartz veins containing pyrite and gold were opened by cuts and small shafts. There was a mill on the property before the Civil War, but little mining seems to have been done. After the war a shaft is said to have been sunk to a depth of 150 feet but nothing further was done.

The Greeley Mine.

Location.—The Greeley mine, lying on the headwaters of Hatcher Creek, is situated about 1½ miles southeast of Alpha, a station on the Buckingham Branch of the Chesapeake and Ohio Railway, and a mile southwest of Gravel Hill.

History.—The placer deposits at the Greeley mine, formerly known as Ayres' mine, were worked during the early days of gold mining in this

^aHenwood, W. J., *Op. cit.*, pp. 282-283.

^b*Ibid.*, pp. 282-283.

^cCredner, H., *Op. cit.*

^dHenwood, W. J., *Op. cit.*, p. 384.

county, and it is reported the branch gravels yielded much gold. Prospecting has been carried on at various times in the endeavor to locate the vein from which the placer gravels derived their gold, and many pits, trenches, and shafts have been opened with this object in view, but to-day they are all caved. There are several large trenches, leading toward the top of a hill, the largest being 30 to 40 feet wide, about the same depth, and several hundred feet long in a northeast-southwest direction. While these trenches look rather large for the purpose, they are said to have been cut while prospecting for the vein. When Credner visited the mine in 1865 a mill was being started, but it was probably never finished, and except for the placer washing no mining has been done on the property.

Veins and country rock.—Several veins were located by open pits and one of them is reported to have carried free gold, but the vein quartz exposed when the property was visited by the writer showed little evidence of mineralization.

The lack of outcrops on the property and in its immediate vicinity makes it difficult to draw conclusions in regard to the country rock. A few pieces of quartz-sericite schist are found on the surface, and at a distance of a mile or more northeast and southwest along the strike of the formations, schists and quartzites are exposed which apparently belong to the same series as the rocks in the bluffs near New Canton.

One of the shafts is sunk in a gray granitic rock (quartz monzonite) which is distinctly schistose. The rock (Spec. 348) is fine-grained and even-granular, and a microscopic examination showed it to be composed of the following minerals, the order given being that of relative abundance: Quartz, biotite, feldspar, hornblende, calcite, garnet, chlorite, magnetite, zircon, and tourmaline. The feldspar corresponds to andesine in composition and shows albite twinning, and orthoclase if present is rare. The biotite is dark brown in color with strong absorption. Hornblende occurs in light to dark green crystals, with ragged outline, and low interference colors. Calcite which is fairly abundant frequently shows multiple twinning. The garnets which are light pink in color show ragged outlines and contain numerous inclusions of the other minerals. Both biotite and hornblende show alteration to chlorite which is dark green in color. Magnetite occurs in clusters of small grains and zircon is quite plentiful as inclusions. A prism of tourmaline is present in the slide. It is strongly pleochroic changing from reddish-brown to dark green.

Much of the rock is cut by veinlets ranging up to 2 inches or more in width, but mostly less than an inch. In places calcite forms one side

and quartz the other of a veinlet, but usually they are intermixed, quartz occurring in calcite and calcite in quartz. Often the veinlets are much contorted, and again they branch and intersect. The contact between the rock and the veinlets is not always perfectly sharp but shows a slight gradation. Occasionally large crystals of muscovite 4 or 5 cm. in diameter are intercrystallized with the quartz and calcite. Where plentiful the flakes of muscovite meet one another at all angles, and the interstitial space is filled with quartz and calcite. Light-colored pyrite is present in the vicinity of some of the veinlets, occurring in cubes 2 to 3 mm. in diameter.

The Lightfoot Mine.

Location.—The Lightfoot mine is situated on the southeast side of Slate River, 2 miles north of Arvonja.

History.—While this property is now better known as a copper mine (see p. 241) it was first worked for gold. It is said that the discovery of the mine was due to Geo. Fisher, who worked the property for several years under lease. After the expiration of his lease it was worked successively by three different companies, who leased it from the proprietor, Mr. Lightfoot. The first of these companies is reported to have made \$300 to \$400 per day stamp-milling for gold. The second company confined its work to surface washing, and the last company developed the copper deposits, shipping 100 tons of \$80-ore to Baltimore, before the mine was closed by the outbreak of the war in 1861. Since that time no work has been done on the gold veins and at present there is little trace of these former operations. In working the placer deposits, gold nuggets worth \$20 to \$30 are said to have been found.

Gold veins.—The country rock in this vicinity is a greenstone schist, which is described in detail on pages 49-51. Credner states that at the time of his visit, in 1865, two gold veins were exposed by pits and shafts which had partly caved. One of these was 4 feet wide and carried iron sulphide and free gold.

Gold has also been found on the Ford property (see p. 243).

CHAPTER VI.

GENETIC RELATIONS OF THE GOLD DEPOSITS.

INTRODUCTION.

The genesis of ore deposits has frequently been regarded as a question of scientific interest only, but with increasing knowledge of the subject it is beginning to be of great practical value from an economic standpoint. The unraveling of the structural relations of ore-bodies, particularly in regions of extensive faulting, has long been recognized as invaluable to the miner, and there is a growing appreciation of the importance of ore genesis. A thorough understanding of the mode of formation and of the subsequent alterations which may have enriched or impoverished an ore deposit, is the only logical basis on which it is possible to predict the continuity and character of the ore-body in depth, or to indicate the probable location of other deposits that may not be exposed.

Previous Theories.

The first geologists to study the gold-bearing veins in this district advanced two antagonistic theories to explain the formation and occurrence of the ore deposits, and both of these theories have had strong supporters. According to one theory, the veins were forcibly injected by igneous agencies into older rocks; and since the lines of least resistance were usually along planes of bedding and schistosity, the veins, as a rule, conformed to the structure of the enclosing formations, although in places they split up and cut across. This explanation was advanced and supported chiefly by Rogers (see page 10). The opposing theory was based on the assumption that the ore-bodies were layers or beds deposited contemporaneously with the enclosing rocks. This explanation as applied to the origin of Virginia gold veins seems to have been advocated first by Clemson and Taylor^a, and was later supported by Silliman, Ansted, Credner, and others. Most of these geologists seem to have ignored the fact that some of the veins in places cut across the bedding of the country rock, but others, following Ansted, attributed this anomaly to changes brought about by "chemical agency" or by a "process of segregation" (see p. 11).

^aClemson, T. G., and Taylor, R. C., The Gold Region of Virginia, Trans. Geol. Soc. Pa., 1835, vol. i, p. 309.

The facts established by the present report in many ways support the views advocated by Rogers but there are certain important exceptions which will be noted later. After examining, at the Tellurium mine, the bed of quartzite known as the "Big Sandstone" vein (see pp. 157-164), it is easy to understand how the early geologists came to regard the veins as sedimentary in origin, for this quartzite is at a glance closely similar to the auriferous quartz veinlets which it encloses.

Types of Deposits.

The primary gold deposits in this district may be divided into two principal types: (1) Veins accompanied by little or no replacement or impregnation of the wall rock, and (2) ore-deposits which have been formed chiefly through replacement—but there is apparently every gradation between the two extremes. Ores belonging to the first type consist essentially of quartz, with more or less feldspar and variable quantities of gold. The sulphides, chiefly pyrite, are always present in small quantities, but seldom average more than 1 per cent. In the ores belonging to the second type, pyrite is the most important constituent and chalcopyrite is fairly common. The veins belonging to the Tellurium system, particularly the "Middle" vein, may be mentioned as typical examples of the first class. The veins at the Young American mine are also of this type, for though there has been in places considerable mineralization of the wall rock, it is nowhere extensive, and is usually in the nature of silicification of the country rock.

The typical replacement deposits were found only in the southern portion of the area in Buckingham County. The London and Virginia vein is an example of the latter class, and the New Canton ore-body probably represents an extreme variety of this type. Under a strictly logical treatment of the subject the genesis of the New Canton ores should probably be considered in this chapter, but because of their localization near an igneous contact, their insignificant gold content, and the fact that they have been worked chiefly for copper, it has been thought best to discuss them elsewhere (see pp. 257-259).

MINERAL COMPOSITION OF THE VEINS.

The consideration of minerals associated with gold is important, not only because of their possible value as indicators of the presence of the precious metal, but also for the reason that such minerals furnish the most reliable evidence bearing on the genesis of the ore-deposits. A table,

summarizing the minerals which have been found in the gold-bearing veins of this district, is given below, together with the names of mines where they have been identified, and the authority for each instance cited. Both the minerals and the mines are listed in alphabetical order. The details in regard to any particular occurrence may be found under the description of the mine in chapter V. The table is limited to minerals found within the quartz veins, and no attempt has been made to list those occurring in the replacement deposits as that would necessarily include all minerals present in the wall rock. Common secondary minerals, undoubtedly derived from one of the primary minerals listed, are also omitted.

List of minerals in the gold veins of the James River basin area, Virginia.

Name.	Mine.	Authority.	Remarks.
GANGUE MINERALS:			
Actinolite	London & Virginia..	Partz, 1854. . . .	Probably in wall rock.
Barite	Do.	Do.	Questionable.
Biotite	Bowles	This report . . .	Probably derived from in- clusions of wall rock.
Do.	Waller	Do.	Along the walls of the vein.
Do.	Young American	Do.	Probably derived from in- clusions of wall rock.
Calcite	Morrow	Henwood, 1871	Probably ferrocalcite.
Do.	Waller	This report . . .	Found on the dump.
Do.	Young American	Do.	In vein near wall and along the contact.
Chlorite	Bowles	Do.	Probably from altered in- clusions of wall rock
Do.	Hughes	Do.	Do.
Do.	Morrow	Do.	Do.
Do.	Scotia	Do.	Do.
Do.	Tellurium	Do.	Do.
Do.	Waller	Do.	Do.
Do.	Young American	Do.	Do.
Cyanite	Young American	Do.	Do.
Feldspar	Benton	Do.	Kaolinized feldspar in ore on dump.
Do.	Bertha and Edith...	Do.	Do.
Do.	Buckingham	Do.	Plagioclase feldspar in vein quartz on dump.
Do.	London & Virginia..	Do.	Do.
Do.	Morrow	Henwood, 1871	With quartz and calcite as veinlets.
Do.	Moss	This report . . .	Kaolinized feldspar in ore on dump.
Do.	Scotia	Do.	Oligoclase-andesine.
Do.	Tellurium	Do.	Do.
Do.	Waller	Do.	Albite-oligoclase to oligo- clase.
Do.	Young American	Do.	Dominantly andesine or oligoclase-andesine.
Garnet	Bowles	Do.	Probably due to inclusion of foot-wall material.
Do.	Morrow	Henwood, 1871	Do.
Hornblende	Do.	This report . . .	Do.
Do.	Scotia	Do.	Do.
Do.	Waller	Do.	Found on old dump.
Muscovite (including sericite)	Benton	Do.	Probably chiefly secondary from feldspars.
Do.	Bertha and Edith...	Do.	Do.
Do.	Bondurant	Do.	Do.
Do.	Bowles	Do.	Do.
Do.	Buckingham	Do.	Do.
Do.	London & Virginia..	Do.	Do.
Do.	Morrow	Do.	Do.
Do.	Moss	Do.	Do.
Do.	Scotia	Do.	Do.
Do.	Tellurium	Do.	Do.
Do.	Waller	Do.	Do.
Do.	Young American	Do.	Do.

*List of minerals in the gold veins of the James River basin area, Virginia—
(Continued).*

Name.	Mine.	Authority.	Remarks.
GANGUE MINERALS:			
<i>(Continued)</i>			
Quartz	All the mines.....	.....	.....
Selenite	Buckingham or London & Virginia	Henwood, 1871	Questionable.
Talcite	Buckingham or London & Virginia	Partz, 1854....	Do.
Tourmaline ...	Bowles	This report ...	Gold Hill vein.
Do. ...	Moss	Do. ...	In vein quartz, associated with pyrite.
Do. ...	Young American	Do. ...	In vein quartz, associated with gold and cyanite.
ORE MINERALS:			
Chalcocite	Buckingham	Henwood, 1871	Description indicates min- eral is secondary.
Do.	London & Virginia }		
Chalcopyrite ...	Buckingham	Partz, 1854; Ansted, 1854; Henwood, 1871	
Do.	London & Virginia }		
Do. ...	Morrow	Partz, 1854....	Mentions presence of cop- per without stating the mineral.
Do.	Snead	Credner, 1869..	
Do.	Young American	This report ...	
Galena	Buckingham	Credner, 1869; Henwood, 1871	
	London & Virginia }		
Do.	Snead	Credner, 1869..	
Gold	All the mines.....	.....	
Ilmenite	Scotia	This report ...	Rare.
Do.	Young American	Do. ...	Rare.
Leucoxene	Do.	Do. ...	Rare.
Magnetite	Bertha and Edith...	Do. ...	Associated with pyrite.
Do.	Bowles	Do. ...	"Back Field" vein.
Do.	Young American	Do. ...	Associated with pyrite.
Marcasite (?)..	Young American	Do. ...	In vug-like opening, proba- bly left by pyrite.
Pyrite	All the mines.....	.....	
Pyromorphite ..	Buckingham	Henwood, 1871	
Do.	London & Virginia }		
Do.	Snead	Credner, 1869..	
Pyrrhotite	Waller	This report ...	Found on old dump.
Sphalerite	Snead	Credner, 1869..	
Do.	Tellurium	This report ...	Rare.
Do.	Young American	Do. ...	Rare.
Tellurium (?)..	Tellurium	Credner, 1869..	Probably tetradyomite.
Do.	Morrow	Henwood, 1871	Do.
Tennantite	London & Virginia..	Genth, 1855....	Given as tetrahedrite by Becker.
Tetradyomite ...	Tellurium	Fisher, 1849; Genth, 1855..	Rare.
Do. ...	Young American	This report ...	Rare.

Description of the Gangue Minerals.

Quartz is always the most abundant gangue mineral. It varies from milky white and translucent to clear and glassy. It is coarsely crystalline, in places approaching saccharoidal in texture, and is apparently the same wherever it occurs in well-defined veins, lenses, or as a replacement mineral. Crystal faces are rare except along joint planes and in cavities left by the removal of pyrite, where they are probably due to the enlargement of primary individuals by deposition of a little secondary silica. Examined microscopically, the quartz frequently shows some optical distortion but little or no granulation or other evidence of crushing. The individual grains have irregular interlocking boundaries and average from 1 to 3 mm. in diameter. Gas- and fluid-filled cavities are common, sometimes occurring in irregular branching and interlaced forms, but more often in smaller spherical and elliptical shapes, which are usually grouped in rows or planes that occasionally extend unbroken from one crystal individual to another.

Feldspar is the second gangue mineral in relative abundance, having been identified in all veins that were well exposed, and in places constitutes as much as 10 per cent. of the vein material. It occurs in angular crystals, ranging up to 1 cm. or more in diameter, scattered through the quartz, but is usually much more plentiful near the walls of the veins. In some of the smaller veins, and in places where quartz lenses narrow and pinch out (see fig. 14), feldspar is sometimes for a limited distance practically the only constituent. When fresh, the feldspars are white to light yellow or light pink, and are often difficult to distinguish from the quartz without careful examination. In the upper portion of the veins above water level the feldspars seem to be entirely kaolinized, but wherever specimens could be obtained, sufficiently unaltered for identification by optical methods, they proved to be soda-lime plagioclase, ranging from albite-oligoclase to andesine. No orthoclase or albite could be distinguished in any of the veins. In thin sections under the microscope the feldspars commonly show albite twinning but many of them are entirely unstriated. There is no evidence of optical distortion, granulation, or other pressure effects. In places a little sericite is present as an alteration product of feldspar, occurring in clusters of curved and radiating scales, but kaolin is the chief secondary mineral. The feldspars are probably of earlier crystallization than most of the quartz.

White potash mica is one of the important gangue minerals, apparently occurring in all of the veins. Some of it is in large flakes such as are usually called muscovite, while much is in the form of shreds and scales,

evidently secondary in origin, and commonly designated as sericite. Sericite is a prominent constituent of the wall rocks and is especially plentiful in some replacement deposits.

Biotite and chlorite are frequently present in the veins, but their occurrence is such as to suggest that they were chiefly if not entirely formed from inclusions of country rock through alteration by vein-forming solutions. The chlorite is partly secondary after biotite and partly derived from hornblende; it is doubtful if any of it is an original constituent of the veins. Garnet and hornblende rarely occur within the quartz veins and where identified were found close to the walls. These four minerals are occasionally prominent in the wall rock, and their occurrence and distribution indicate that their formation was chiefly due to metamorphic agencies accompanying the formation of the veins.

Black prisms of tourmaline, usually arranged in radiating groups, occur in some of the gold-bearing veins, and one specimen was found showing visible gold resting on tourmaline (see p. 131). Tourmaline was seen in association with auriferous pyrite, and was also identified in a piece of vein quartz containing cyanite. Tourmaline was not noted in any of the veins containing much feldspar, and seems to be most plentiful in certain bold outcrops of white quartz, which show little evidence of mineralization and contain only traces of gold.

Cyanite was identified in only one of the gold-bearing veins (see pp. 128-129), but was found in several quartz veins not known to contain gold. It was found in metamorphosed wall rock close to veins under conditions that indicate its origin was due to vein action.

Description of the Ore Minerals.

Gold occurs chiefly in quartz and mechanically enclosed in pyrite, always so far as known in the native state. In the oxidized ores it is frequently found in cavities associated with limonite. It was seen in small scales, grains, and irregular wire-like masses ranging up to 3 mm. in length, and much larger particles have been reported from some veins. No evidence of crystal form could be distinguished. Gold was found in feldspar and in kaolin derived from feldspar. At the Young American mine the presence of chalcopyrite in the ore is considered a favorable indication. Gold was identified in association with tetradymite at the Young American mine, and at the Tellurium mine it is said to occur interfoliated with that mineral. At the former mine gold was found resting on tourmaline.

Silver is usually present in traces, probably alloyed with the gold. It is said to be abundant in some of the ore at the London and Virginia mine, and argentiferous galena has been reported at the Page mine.

Pyrite is the most abundant of the ore minerals and usually carries gold values. In veins belonging to the Gold Hill system it occurs in large cubes, 1 cm. or more in diameter, but elsewhere it is fine-grained. Cubes are the commonest crystal form, pyritohedrons are also present, and octahedral faces may occasionally be identified. The pyrite rarely constitutes any considerable proportion of the quartz veins, and where it is unusually abundant the gold content is apt to be higher. Occurring as a replacement mineral in the schists and quartzite it sometimes forms 90 per cent. or more of the rock mass. At the Moss mine it occurs associated with tourmaline. Limonite is the common alteration product, and in places magnetite is associated with the pyrite in such way as to suggest its possible formation through partial oxidation of the sulphide. Unstained quartz from the Gold Hill veins frequently contains large cubical cavities from which pyrite has been wholly or partly removed. This phenomenon may be due to solution by ferric solutions or sulphuric acid instead of direct oxidation. Secondary sulphides occur along joint planes in some of the lowest workings.

Pyrrhotite is not common and occurs chiefly in altered wall rock close to the veins. Chalcopyrite is the most abundant sulphide after pyrite, but is not an important constituent except in the replacement deposits, and there it is largely secondary, occurring chiefly in zones of enrichment near water level. Chalcocite has been identified only in replacement deposits and is probably all secondary. Galena and sphalerite are both rare.

Tetradymite, a telluride of bismuth, is sparingly present at two of the mines, and the failure to identify it elsewhere is probably due to the lack of sufficient exposures as much as to its rarity. While always occurring in small quantities this mineral has been identified at many gold mines in the eastern gold belt, and seems to be one of the distinctive minerals.

Manganese minerals were not recognized in the unaltered ores below water level, but in the oxidized zone near the surface black stain (probably psilomelane) is common along joint planes and fractures.

Summary.

A number of the vein-forming minerals are of rare occurrence in gold-bearing deposits, and cyanite and soda-lime feldspar have not previously been reported. The character and association of many of the minerals are

indicative of deep-seated origin, under conditions of great pressure and high temperature. The presence of soda-lime feldspars in gold-quartz veins is of considerable importance because of its bearing on the theories of ore genesis. The occurrence of these feldspars as primary constituents in rocks has been considered the strongest evidence of igneous origin.

GENESIS OF THE DEPOSITS.

In presenting the data contained in the previous sections of this report, it has been assumed that the ores were deposited from aqueous solutions. This theory of vein formation is so well established that it is unnecessary to discuss it here. From facts which were developed in the detailed descriptions and which will later be assembled for further consideration, it is believed that the solutions were magmatic in origin.

The theory of a magmatic origin for gold-quartz veins has been developed within the last 15 years by Vogt, Spurr, Kemp, and others. The formation of this class of veins is closely related to the formation of pegmatites—a question which has interested geologists for nearly a hundred years. It would be out of place in a report of this kind to enter into a detailed discussion of the voluminous literature bearing on the subject, but, for a proper understanding of the argument which follows, it is necessary to outline the theory of magmatic differentiation in so far as it applies to vein formation.

The microscope has shown that in granites and similar rocks, the order of mineral crystallization is not that of relative fusibility; and synthetical experiments have proven that certain minerals always present in granites, can not be formed by dry fusion without the aid of water or other mineralizers. These minerals are more abundant and better developed in pegmatites—rocks which accompany and in places pass by gradation into the large granite masses with which they are commonly associated. Not only has it been found that every intermediate gradation exists between granite and pegmatite, but that pegmatites, by decrease of feldspar, pass into quartz veins, apparently similar to those which are known to be deposited from circulating solutions. The microscopic study of granites in thin sections, together with chemical analyses, proves that the mineral constituents—especially quartz, the last to crystallize—contain inclusions of primary water which was imprisoned in the solidifying rock. It is believed that the original magmas, from which granites are formed, contain water and other gases, and that as crystallization progresses these are gradually concentrated in a residuum. Pegmatites, and later quartz veins,

are formed from this residual magma as it, through partial crystallization, becomes richer in water and relatively poorer in the minerals which are of early formation. In this process of differentiation it is impossible to draw sharp lines for, as Spurr states, "At one end of the series the true granites are not wholly igneous, and at the other end the quartz veins are not wholly aqueous. The processes which formed them all are nearer together than these terms signify."^a

The veins considered in the present report appear to be farther removed from the aqueous end of the series, and more closely allied to pegmatites than any gold-bearing veins which have previously been described. The first part of this chapter dealt with the mineral constituents of the ore-deposits, the succeeding sections will be devoted to the nature of the vein-forming solutions, their source, the conditions governing ore-deposition, and the origin of the spaces occupied by the veins.

Nature of the Solutions.

The best information as to the nature of the ore-forming solutions is furnished by a consideration of the primary minerals in the veins and the character of the changes that have taken place in the wall rock, but the absence of a sufficient number of analyses of the vein material and of the country rock, make anything other than a general discussion of the subject impossible.

Microscopic examination of the vein quartz shows that it contains numerous gas- and liquid-filled cavities, and while analyses of these fluids are not available, their composition may be inferred from that of similar inclusions in granitic quartz which have frequently been analyzed. Such inclusions have been found to consist chiefly of water containing alkaline salts and carbon dioxide. Experiments have proved that silica, gold, and the sulphides of arsenic, antimony, iron, copper, lead, and zinc, are soluble in waters containing carbonates and sulphides of the alkalies, and their solubility is probably much greater under the conditions of high temperature and pressure which obtained in the ore-depositing solutions.

The solutions must have carried large amounts of silica, and the production of feldspars and mica indicates that aluminum, sodium, calcium, and potassium were present in about the order named. The sulphides of iron, copper, zinc, and lead are all primary minerals, and were therefore essential constituents of the ore-forming solutions. Gold was also present

^aSpurr, J. E., *Ore Deposits of the Silver Peak Quadrangle, Nevada*, Prof. Paper, U. S. Geol. Survey, No. 55, 1906, p. 131.

and at least some of the solutions contained bismuth and tellurium. While carbonates were noted in only a few of the veins, carbon dioxide was probably a constant constituent. The mineral tourmaline, which is of rare occurrence in gold-bearing veins, contains boron, and some geologists have attributed to this element unusual properties as a mineralizing agent. Fluorine has been found necessary for the artificial production of mica, and Spurr has suggested that the alteration, near mineral veins, of orthoclase to muscovite or sericite, is due to the presence of fluorine in the mineralizing waters.^a The absence of orthoclase from the veins in which feldspars were identified, although a little potash mica is of common occurrence, indicates the possibility of some such action, but no fluorite, apatite, or other fluorine-bearing mineral was noted in any of the ore-deposits.

The question of the degree of concentration which obtained in the ore-forming solutions is an interesting one, but until more experimental work has been done on the synthesis of vein minerals under varying conditions, it must, for the most part, remain unanswered. It is probable that under the unusually high pressures and temperatures, which are believed to have prevailed during ore-deposition, the concentration was relatively high—how high is not known.

The presence of much soda-lime feldspar in some of the veins, and occasionally of the minerals, tourmaline and cyanite, point to unusual conditions in the formation of gold deposits. The character and association of these minerals, together with the extensive alteration of the wall rocks, are indicative of a deep-seated origin under conditions of high temperature and great pressure. The metamorphism of the wall rock in many places is similar to that produced by igneous intrusions, and is accompanied by the production of such typical contact minerals as garnet, hornblende, biotite, sericite, tremolite, and cyanite. In view of these facts it seems unquestionable that the temperature and pressure must have been much higher than those which usually prevail during the formation of gold veins. With the present knowledge of the subject any estimate of the probable temperature and pressure of vein-forming solutions must necessarily be rough, but an attempt may be of value and serve to bring out additional data bearing on the question.

Wright and Larsen, as a result of their investigations, reached the conclusion that vein and geode quartzes and coarse-grained siliceous pegma-

^aSpurr, J. E., *Geology of the Tonopah Mining District, Nevada*, Prof. Paper, U. S. Geol. Survey, No. 42, 1905, p. 231.

tites were formed below 575° C., while graphic pegmatites, granites, and porphyries were in all probability crystallized above 575° .^a If the same relation holds in regard to the gold veins described in this report, they must have been deposited at temperatures below 575° C., and from the metamorphic effects on the wall rocks and the character of some of the vein minerals, it is believed that the temperature of the vein-forming solutions was probably above the critical temperature of water, which is about 365° .

Becker, Graton, Lindgren, and others have recognized that the southern gold veins originally extended far above their present outcrops and it has been estimated that a depth of possibly 15,000 or 20,000 feet may have been removed by erosion.^b Taking the average specific gravity as 2.7, the rock pressures at these depths would be, respectively, 17,550 and 23,400 pounds per square inch. From facts which will be considered in detail in discussing the origin of the spaces occupied by the veins, the writer believes that the veins were formed in the zone of fracture and flowage as defined by Van Hise. There is evidence that, at the time of vein formation, hard quartzites were deformed chiefly by fracturing, while the softer rocks with which they are interbedded, adjusted themselves to unequal strain by flowing. The schists exposed at the Tellurium mine are the weakest rocks found enclosing veins, and their crushing strength is probably greater than that of good roofing slates, for they have undergone greater recrystallization. The crushing strength of strong slates averages from 15,000 to over 30,000 pounds per square inch. While the figures given above are only roughly approximate they serve to indicate the great pressures which prevailed during the formation of the veins. For the rocks under consideration the higher figure is probably more nearly correct.

Source of the Material.

The composition of the gold-bearing veins is independent of the character of the wall rock, which varies greatly in different localities; and therefore it is improbable that the vein material could have been derived from the enclosing formations. On the other hand, the composition and texture of some of the veins closely resemble that of pegmatites, and it is difficult, if not impossible, to account for the presence and association of such minerals as tourmaline, magnetite, ilmenite, and much soda-lime feldspar, on any hypothesis other than that of magmatic origin.

^aWright, F. E., and Larsen, E. S., Quartz as a Geologic Thermometer, *Amer. Jour. Sci.*, 1907, vol. xxvii, pp. 446-47.

^bLindgren, W., Notes on the Dahlonga Mines, U. S. Geol. Survey, Bull. 293, 1906, p. 124.

Additional evidence in favor of this hypothesis is furnished by the alteration of the wall rock, an alteration which in places resembles on a small scale the contact metamorphism produced elsewhere in the area by the intrusion of granite into older sedimentaries. The great depth at which the veins were formed and the conditions of high temperature and pressure which must have prevailed, have already been discussed. It is obvious that the solutions from which the ore-bodies crystallized must have originated at points of even higher pressure and higher temperature; for in moving upward the pressure would decrease, and some heat be expended in raising the temperature of the surrounding rocks. These conditions would be fulfilled if we assume the presence of an underlying mass of igneous rock, and this conclusion was reached by an entirely independent line of reasoning (see pp. 102-103).

An examination of the geological maps (Pls. I and II) shows that most of the gold-bearing veins are distributed in belts that roughly parallel the known contacts between intrusive granite and older sedimentaries. In the chapter on structure and metamorphism evidence was presented in support of the hypothesis that the veins are located chiefly along the limbs of anticlinal folds, and that the underlying granite extends highest in the crests of these folds.

Another line of argument helping to prove a connection between the veins and granite is furnished by evidence bearing on their relative age—evidence which indicates that the formation of the veins marked the close of the period of granite intrusion and that they were not improbably contemporaneous in origin with the pegmatites and other residual differentiates.

If the solutions that deposited the ore-bodies were derived by differentiation from the original granite magma, the granite itself would be expected to contain some gold, although the quantity might be so extremely small as to make its detection difficult and its quantitative determination impossible. Two samples of granite were tested in order to ascertain, if possible, the presence of any gold. One of these samples consisted of gneissic granite from the quarry at Columbia, and upon assaying it gave negative results. The other was obtained from an outcrop of weathered granite on the farm of H. Williams, one mile northeast of Rivanna Mills. After removing several inches of the partly decomposed rock in order to insure against possible contamination, an average sample was taken over an area of several square feet, and this was quartered down to give a final sample of about 5 pounds. A careful assay of this yielded 0.015 ounce of gold per ton, equivalent to about \$0.31.^a

^aThese two assays were made by E. E. Burlingame & Co., Denver, Colorado.

In prospecting for gold, a 15-foot shaft was sunk on a pegmatite dike, located about 400 yards north of the granite outcrop described above. The pegmatite is partly fine-grained, but contains large angular masses of quartz showing a little pyrite (see sketch, p. 74). Mr. Williams states that some of this quartz assayed nearly \$3.00 gold per ton.

The results given above prove that the granite does carry gold in places, and while it would be rash to draw conclusions without taking a large number of samples, it is interesting to note that the granite in which gold was identified, is the porphyritic variety showing only slight schistosity, and that it is located near the crest of the hypothetical anticline (see pp. 98-99), at a point where the granite is believed to have been formerly covered by schists at no great distance above the present surface.

Deposition of the Ores.

The manner in which ores are deposited and the causes which bring about precipitation are of the utmost importance in any consideration of their genesis, but exact knowledge on this subject is as yet very limited. In this district, the inaccessibility of most of the underground workings, which confined the detailed examination of ore-bodies to a very few localities, and the lack of a sufficient number of analyses, necessitates that the discussion of this subject be extremely limited.

The precipitation of ores from solution may be brought about by any one of the following causes, or by two or more of them acting together:

- (1) Change in temperature.
- (2) Change in pressure.
- (3) Change in chemical composition due to
 - (a) loss of some substance from the solution;
 - (b) mixture with other solutions;
 - (c) reaction between the wall rock and solution.

It has been shown that the temperature and pressure of the ore-bearing solutions must have been higher at the points of origin than they were where deposition took place. Decrease in temperature was probably the chief cause in bringing about the separation of the gangue minerals, and possibly of the ore minerals as well. The effect of changes in pressure is not so well known, but certainly in the case of quartz, decrease in pressure is an important factor in causing supersaturation. The separation of some of the gangue minerals may have altered the composition of the solutions to such an extent that other minerals were thrown down. It is doubtful

whether the solutions mingled to any extent with other solutions differing in chemical composition, for meteoric waters could hardly be abundant at a depth where the pressure was sufficient to prevent the formation of appreciable openings.

Reaction between solutions and wall rock seems to have been an extremely variable factor in the deposition of the ores, and while these variations may in part be explained by differences in the character of the wall rock, many things indicate that there was probably considerable difference in the composition of the ore-forming solutions in different parts of the district. North of James River there is little evidence of important changes in the chemical composition of the wall rock. In places there has been considerable metamorphism, resulting in recrystallization and the formation of new minerals, but the changes in chemical composition are comparatively slight, and are chiefly due to silicification. Sulphides have replaced some of the minerals in the wall rocks but usually to a very limited extent.

In some of the ore-deposits south of the river, such as the London and Virginia vein, chemical interchange between the solutions and wall rock has been of the utmost importance. Porous rocks are of course most readily penetrated by solutions, and this may help to explain the occurrence of the replacement deposits in quartzites and quartz schists. In these deposits the chief replacement mineral is pyrite. The iron-bearing minerals in the country rock seem to have been attacked first, but in places practically all of the quartz has been replaced. Feldspars, if present, were altered to sericite, and this mineral is about the only gangue mineral left in some of the ores that are most concentrated.

While nothing definite is known concerning the rate of ore deposition, the formation of the deposits was probably exceedingly slow and extended over a considerable period of time. This is indicated by facts connected with the probable manner in which the spaces occupied by the veins were formed—a question which is considered in detail in the following section.

Origin of the Spaces Occupied by the Veins.

Formerly it was generally believed that all true veins were deposited by aqueous solutions circulating through preëxisting fissures. That some veins were formed in such openings is indicated by the presence of symmetrical banding, comb structure, and similar evidence, but in recent years doubts have arisen as to whether all veins could have been formed in this manner. The theory of replacement is applicable in many cases but

does not furnish a satisfactory explanation of the origin of veins which are accompanied by little or no replacement of the wall rock.

As early as 1898, Russell, in describing certain "brecciated veins," stated that the separation of the rock fragments "seems to be due in part, at least, to the crystallizing of the quartz and calcite." He suggests "that these minerals, in crystallizing, have exerted a force analogous to the expansion of water on freezing, which has crowded the rock fragments asunder."^a

The fact that growing crystals exert a linear pressure in the direction in which they grow, was noted by Jean Lavalley in 1853,^b but no quantitative experiments seem to have been attempted until Becker and Day began their investigations. In 1905, Becker and Day, as a result of their experiments, stated: "It was at once evident that it [the linear force of growing crystals] amounted to many pounds per square inch, and as observations multiplied, it became reasonably certain that it is actually of the same order of magnitude as the ascertained resistance which the crystals offered to crushing stresses."^c In conclusion they called attention to the geological importance of the force of crystallization and pointed out the possibility of its action in widening quartz veins.

Graton, in studying the gold-quartz veins in North and South Carolina, reached the conclusion "that the solutions, pushing their way along what may in many cases have been the merest fractures, actually forced the walls apart and made receptacles in which their load was deposited."^d

Lindgren, advocating the explanation advanced by Graton as opposed to the hypothesis that veins could be formed through the force of crystallization, states that "it scarcely seems possible to attribute such power to it as would be necessary to force deep-seated crevices apart to form room for the crystals, and another strong objection is that it would seem impossible that under these conditions comb structure and coarsely even-grained quartz could be produced."^e

The study of veins in the Virginia area, and especially of those exposed at the Tellurium mine, has convinced the writer that the force

^aRussell, I. C., A Preliminary Paper on the Geology of the Cascade Mountains in Northern Washington, 20th Ann. Rept. U. S. Geol. Survey, 1898-99, pt. ii, p. 207.

^bCompt. Rend., 1853, vol. xxxvi, p. 493.

^cBecker, G. F., and Day, A. L., The Linear Force of Growing Crystals, Proc. Washington Academy of Sciences, 1905, vol. vii, pp. 286-287.

^dGraton, L. C., Reconnaissance of Some Gold and Tin Deposits of the Southern Appalachians, U. S. Geol. Survey, Bull. 293, 1906, p. 60.

^eLindgren, W., The Relation of Ore-Deposition to Physical Conditions, Economic Geology, 1907, vol. ii, p. 107.

exerted by growing crystals must have been the chief factor in the formation and enlargement of these gold-bearing veins. A discussion of the facts on which this conclusion is based, is given below.

The "Middle" vein at the Tellurium mine consists of a series of lenses, varying in size, but remarkably symmetrical in form (see figs. 13-15). Horizontal sections through these lenses resemble the vertical sections in every way. The wall rock is a fine-grained, highly foliated schist containing scattered crystals of garnet, and closely approaches a slate in perfection of cleavage and fineness of texture. The schistosity is parallel to the bedding and older than the formation of the vein, which is conformable in strike and dip. Thirty feet northwest of the "Middle" vein the schist is interbedded with a layer of quartzite about 6 feet thick, known as the "Big Sandstone" vein. This quartzite is also slightly schistose parallel to the bedding. It encloses veinlets similar in composition and texture to the "Middle" vein and evidently formed at the same time and in the same manner, but these veinlets frequently cut across the schistosity of the enclosing rock (see fig. 12). A detailed description of these veinlets and of the "Middle" vein, together with a petrographic description of the wall rocks, is given on pages 157 to 170.

The fact that the veins of this district show practically no crushing or other evidence of deformation, although the surrounding country rock is intensely foliated, is sufficient proof of their formation since the crustal movements that produced the schistosity, and moreover in some of the harder rocks they occasionally cut directly across the prevailing schistosity.

The space occupied by lenticular veins is sometimes accounted for on the supposition that displacement has occurred along an irregular fault, but in the case of veins like the "Middle" vein, this explanation would be improbable, in view of the symmetrical shape of the lenses, which is the rule even where adjoining lenses differ greatly in size. This argument is confirmed by the fact that the folia of the enclosing schist, where in contact with the vein, conform absolutely to the curvature of the lenses. It may also be mentioned that single detached lenses are occasionally present near some of the veins (see Pl. X, fig. 2) and such occurrences can not be explained by any method of faulting. In passing away from the lenses the flexures in the schist gradually straighten, so that at a distance of about 2 feet the cleavage is straight and uniform.

From the facts stated above, it is concluded that the "Middle" vein could not have been formed in a preëxisting fissure, and since the contacts with the wall rock are sharp and without evidence of replacement, the

lenticular spaces must be due to pressure. That the rock pressure during vein-formation was greater than the crushing strength of the schist, is proved by the uniform curves of the folia—the schists have made room for the lenses by flowing and not by fracturing. The faint line connecting the lenses shows that the ore-bearing solutions, following the lines of least resistance, entered along the planes of bedding and cleavage; but great pressure was necessary to expand such microscopic openings into lenses 2 or 3 feet in thickness. How could such a pressure be developed?

There are two hypotheses that may be advanced to account for the existence of such pressure: (1) The ore-bearing solutions were forced in from below under sufficient pressure to push the walls apart, and (2) the pressure was exerted by the crystallization and growth of the vein-forming minerals.

The chief argument against the first hypothesis is the symmetrical and, in places, almost spherical shape of the lenses. If the expansion of the openings was due to fluid pressure exerted by the ore-bearing solutions, the pressure would necessarily have been equal at all points of contact between the fluid and the walls, except for the slight variations due to friction and difference in elevation. The enclosing schists are apparently uniform in texture and composition, and therefore would offer uniform resistance to the fluid pressure at all points, except those lying in the plane of cleavage along which the solutions entered. Under these conditions very flat lenticular- or tabular-shaped openings must have been formed. In explaining, by means of this hypothesis, the formation of a series of openings similar to the lenses shown in figs. 13 and 15, it would be necessary to assume the presence of areas of unusual weakness at every point where an enlargement of the vein occurred. Moreover, since most of these enlargements are symmetrical, it would be necessary to assume that, at these points, there were similar areas of weakness on both sides of the cleavage plane. Such assumptions are almost inconceivable.

Unless the spaces were filled by ore-deposition as soon as formed, the fluid pressure would have to be uniformly maintained in order to prevent the walls from collapsing. The great fluidity of the solutions is indicated by the microscopic size of some of the openings along which they entered. Additional evidence against the formation of the openings by fluid pressure is furnished by the existence of large lenses, consisting of a number of smaller quartz lenses separated by feldspar and layers of schist. (See fig. 14.)

In a previous paragraph it was mentioned that the veinlets occurring in the bed of quartzite frequently cut across the schistosity. This is ex-

plained by the greater rigidity and more nearly massive texture of the quartzite which caused it to rupture under the forces of deformation while the weaker schist yielded by flowing. In other words, the rigidity of the quartzite under the conditions of vein-formation was probably greater than the rock pressure, while that of the schist was less. The line of least resistance for the ore-bearing solutions which entered the quartzite was frequently along minute fractures instead of along the poorly developed cleavage planes, and therefore the veinlets do not always conform to the structure of the enclosing rock. If the spaces occupied by the veins are due to fluid pressure, it is difficult to understand why veins a foot or more in width were formed in the quartzite, when the less rigid schist was present on either side. Under these conditions veins might be expected along the contact between the quartzite and schist, or wholly within the schist, but not in the quartzite.

In view of all of the facts outlined above, it seems very improbable, if not impossible, that the vein spaces could have been produced by fluid pressure and then filled by ore-deposition.

According to the second hypothesis, the solutions entered along narrow openings—probably capillary or subcapillary in size—and while under pressure, the pressure was insufficient to expand the openings. Crystallization began at favorable points, possibly about grains of quartz, and as the crystals grew, the walls were locally pushed aside. At first a growing lens may have consisted of a single crystal, but as the folia began to separate, others would form in the space created immediately around the original crystal, where the pressure was lowered by its supporting effect. Since the resisting pressure was equal on opposite sides of the cleavage plane the growth would be symmetrical with reference to that plane. When once started a lens would continue to grow as long as the material for growth was available.

There are many points of similarity between the formation of these lenses and the growth of chert concretions in limestones, or of garnets and similar pseudophenocrysts in fine-grained schists. The localization of growth is probably due to the physico-chemical law by which solutions become supersaturated with respect to large crystals, while at the same time they may exert a solvent action on small crystals of the same substance.

When individual crystals are enlarged their shape is controlled by the tendency to form crystal faces, by the external forces resisting growth, and by the accessibility of the material from which they are composed. When

masses, consisting of numerous crystals, are enlarged by crystal growth, the resulting shape is controlled chiefly by the forces resisting expansion. The schist enclosing the lenses described above has a much greater tensile strength parallel to the schistosity than across it, and the folia offer considerable resistance to rupture, even when the rock is under sufficient pressure to make it more or less plastic. The resistance offered by these folia to the enlargement of the ore-bodies is somewhat analogous to surface tension, which in liquids causes the assumption of shapes giving a maxi-

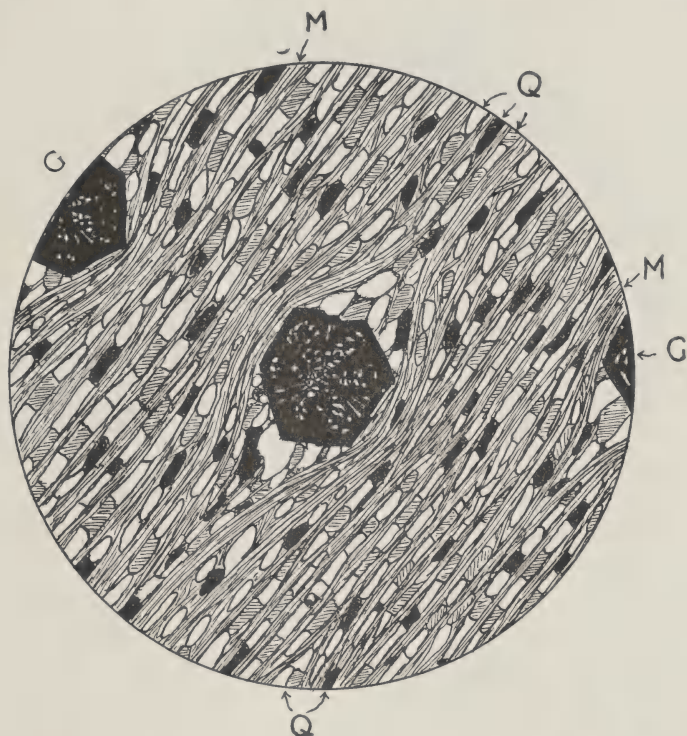


Fig. 21.—Sketch showing recrystallization of quartz about garnets which are of later origin than the foliation of the schist. Thin section cut at right angle to cleavage. With analyzer. Q, quartz; M, mica; G, garnet. Enlarged about 20 diameters.

mum volume for a minimum exposure of surface. The solubility of quartz decreases with decrease in pressure and supersaturation is reached first where the pressure is lowest. If the resistance to growth were equal in all directions spherical bodies would be formed instead of lenses, and under any given condition the shape produced is that shape which requires the least expenditure of energy.

The fact that difference in pressure may be an important factor in determining the location of crystal growth, is strikingly illustrated by the recrystallization of quartz around the garnets occurring as pseudophenocrysts in the knotted schists of the area. These schists form the wall rock of the "Middle" vein, and it should be noted that where this variety of garnet schist has been found elsewhere in the area, it occurs only in the immediate vicinity of granite contacts. The garnets are of later origin

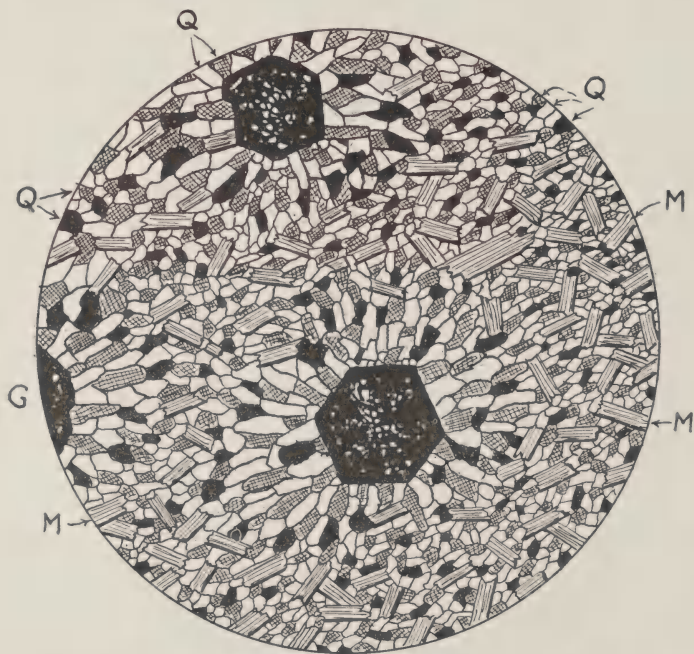


Fig. 22.—Sketch showing radial arrangement of quartz in garnetiferous schist. Thin section cut parallel to cleavage. With analyzer. *Q*, quartz; *M*, mica; *G*, garnet. Enlarged about 15 diameters.

than the schistosity of the rock, and it is believed that their formation in the schist at the Tellurium mine, is due to the close proximity of granite rather than the metamorphic action of the vein-forming solutions. In either case their origin must have been practically contemporaneous with the formation of the veins. Under the microscope the schists are seen to consist essentially of elongated quartz grains and small flakes of mica, the two minerals being interleaved to form thin layers or imperfect alternating bands. The garnets in their growth have pushed the folia aside,

and opposite the points of greatest pressure the mica bands run closer together, while the quartz removed from these points has recrystallized between the folia and close to the garnets where the pressure was least. (See fig. 21.) The transfer of the material was undoubtedly due to the small amount of water present in the rock; solution occurred where the pressure was greatest and deposition where it was least. In recrystallizing the quartz grains were roughly oriented so that their greater elongation points toward and away from the garnets. (See fig. 22.)

The partial concentration of feldspar near the ends of quartz lenses, and in small separate lenses practically free from quartz, is caused by the selective power which enables a growing crystal to abstract from solutions material like itself; and this may be taken as additional evidence in favor of the second hypothesis.

An examination of the lenticular veins show that in some instances neighboring lenses in expanding have grown into one another so as to form double lenses, and it is not unlikely that other occurrences of this sort have disappeared through continued growth. The large lenses composed of smaller ones, such as the occurrence shown in fig. 14, were probably caused by the circulation of the ore-forming solutions along several adjoining cleavage planes at the same time, thus permitting the simultaneous growth of lenses at a number of points close together. An alternative hypothesis is that the solutions were deflected into new channels after a lens had been formed causing subsequent deposition to take place about other nuclei located between adjacent folia.

In describing the veinlets occurring in the quartzite, reference was made to the absence of the symmetrical lenses which are characteristic of the vein in the schist. This difference in the shape of the ore-bodies is probably chiefly due to the difference in texture and rigidity of the two varieties of wall rock. If crystallization began at separate points along the fractures in the quartzite and exerted a force tending to open spaces, the rigidity of the rock was sufficient to cause the walls to separate for an appreciable distance beyond the points where the pressure was applied. Any openings formed in this way were filled by deposition from the solutions, and therefore the tendency was to form veins without important variations in width. In other words, rigidity of the wall rock under the conditions of ore-deposition is an essential factor in the formation of veins having a uniform width. This is another illustration of the law controlling the growth of bodies by crystallization, in opposition to outside forces.

The composition of the quartzite has probably aided in producing uniformity in the growth of the veins which it encloses, and this may have

been of as much importance as the rigidity. Since the quartzite is composed almost entirely of quartz grains, the walls of the fractures would furnish innumerable nuclei on which the vein quartz could separate out. In thin sections showing the contact between the quartzite and vein quartz, when examined under the microscope, it may be seen that the quartzite grains along the contact have been enlarged, and that there is therefore a gradation instead of a sharp division in passing from one to the other.

Under the conditions which prevailed during the vein-formation, the gneiss, which forms the wall rock at the Young American mine, appears to have been intermediate in rigidity between the quartzite and knotted schist described above. It was folded and contorted by movements preceding the deposition of the ores, and adjustment took place partly by flowing and partly by minor faulting along fractures and shear zones. The vein-forming solutions entered along these lines of weakness and the enlargement of the openings was brought about by the same causes that operated at the Tellurium. In the gneiss, most of the small quartz masses and some of the larger ones are lenticular in form, but these lenses are flatter and as a rule less symmetrical than those of the "Middle" vein at the Tellurium. They are most plentiful in some of the shear zones. (See fig. 9, p. 130, and Pl. X, fig. 2.)

The hypothesis that vein spaces may be enlarged through the force exerted by growing crystals, furnishes a logical explanation for the presence of numerous detached fragments of the country rock in the veins of some districts. These occurrences have usually been explained on the supposition that the veins were deposited in preëxisting fissures, and that the inclusions represent fragments which have fallen from the walls. That this is sometimes true can not be questioned, though it seems probable that such cases are relatively rare. Where the country rock has been shattered so that numerous small fractures are formed, ore-deposition may take place in any number of them at the same time, and as the veinlets grow the individual fragments of country rock are gradually separated. According to this hypothesis of vein-formation there is no essential difference between the cementation of many breccias and the formation of branching or reticulated veins. The processes by which both are formed are exactly the same and differ only in degree.

At the Morrow mine, in Buckingham County, ore-deposition seems to have occurred in a zone of fracturing; in places the ore-body consists of vein matter with minor inclusions from the walls, while elsewhere the ore occurs in reticulated veinlets which ramify in all directions through the

barren schists that form the country rock. All gradations exist between these two extremes. (See fig. 20, p. 204.) The detached masses of country rock have apparently reached their present positions without noticeable rotation, for as a rule the schistosity of the inclusions is parallel to that of the neighboring walls.

The localization of the veins of this district in or near the more rigid rocks, especially quartzites, is very noticeable, and may indicate that at greater depth where the pressure was necessarily greater the solutions were unable to force their way through the fine-grained and more plastic rocks. The greater porosity of the quartzites may also have been a factor.

General Conclusions as to the Origin of the Gold Deposits.

The primary gold deposits of this area, while varying somewhat in general character, are all intimately related, and owe their origin to the same cause, namely, the intrusion of granitic rocks into the older sedimentaries. They are of two types—quartz veins and replacement deposits—with intermediate gradations between the two extremes. The ores were deposited from highly siliceous and alkaline solutions which ascended from below under great pressure and high temperature. The solutions were magmatic in origin and residual from the crystallization of the underlying granite. This conclusion is borne out by the grouping of the ore-deposits around granite contacts; by the presence and association in the veins of soda-lime feldspar, tourmaline, magnetite, and ilmenite; by the metamorphism of the wall rocks with the production of such typical contact minerals as garnet, hornblende, biotite, sericite, tremolite, and cyanite; by the presence of gold in the granite and its associated pegmatites; and by the evidence as to the relative age of the granites, pegmatites, and veins. It is believed that the precipitation of the ores was due chiefly to decrease in temperature and pressure, though in the replacement deposits interchange of material between the solutions and country rock was an important and perhaps the principal factor.

The ores were deposited at great depths below the surface where the pressure of the overlying rock was sufficient to prevent the formation of open spaces appreciable in size. The solutions forced their way upward along cleavage planes and, in the more rigid rocks, along minute fractures. When deposition began these spaces were gradually expanded by the force of crystallization. The formation of the replacement deposits was probably due to differences in the ore-bearing solutions, but the character of the country rock may have had a determining influence.

The veins in this district differ markedly from the typical auriferous quartz veins of California, which many geologists regard as having been formed by magmatic waters derived from cooling granites. The California veins are much later in origin, have been subjected to less erosion, and therefore their present outcrops were much nearer the surface when ore-deposition took place. This suggests that many of the distinguishing characteristics of the two types are due to the depth below the surface at which the veins were formed. It is not improbable that at greater depth the California veins more closely resemble the gold deposits described in the present report, and that the upper portions of the Virginia veins, long since removed by erosion, were in many respects similar to the veins which are now being worked for gold in California.

SECONDARY ENRICHMENT.

The distribution of the gold in the ore-deposits is a question of great economic importance, and it is regretted that so little is known concerning the subject. The lack of sufficient development work at any of the mines, which were accessible when the area was studied by the writer, makes it impossible to reach definite conclusions in regard to secondary enrichment, and therefore the following discussion is necessarily brief.

The facts gathered indicate that the gold is very irregularly distributed through the veins. There appear to be more or less well-defined pockets or ore shoots of relatively rich ore, but the size and distribution of these is unknown. It is probable that the values vary from point to point in depth as well as along the strike of the veins, and this increases the difficulty of ascertaining the extent to which secondary enrichment has been a factor in determining the present value and distribution of the ores.

It seems unquestionable that the veins were much richer near their outcrops than they are at even a short distance below the surface. The greater production of the mines when they were first worked can not be attributed solely to the fact that the ores were oxidized, and therefore free-milling, for the reports of such reliable observers as Silliman, Ansted, and Henwood, furnish evidence of the unusual richness of the veins when the mines were first opened. Henwood, in describing the Morrow mine, expressed his belief that the gold values decreased in depth (see p. 205), and cited the statistics of production in support of this contention. Ansted, in his report on the same property, mentions that near the surface the gold is indifferently disseminated through the quartz, rotten schists, and enclosing walls, while deeper down it gradually collects together and is found

chiefly within the quartz bands. This local enrichment of the vein and wall rock near the surface, is probably due chiefly to the mechanical concentration of some of the gold formerly contained in the now eroded portions of the ore-bodies, though it is not unlikely that chemical processes have aided in the concentration. Gold is one of the most insoluble substances found in nature, but the long period during which erosion has been almost at a standstill has given every opportunity for concentration to take place through solution and redeposition. Most of the gold that may have been dissolved in this manner was probably reprecipitated before it had been carried far, for precipitating agents were plentiful.

In some of the deeper openings which extended below the oxidized zone, secondary pyrite is found occurring along joint planes and fractures, but the development work is insufficient to determine whether or not there has been any enrichment of the gold values at this depth.

AGE OF THE ORE-DEPOSITS.

Geologists have usually assumed that all the primary gold deposits in the Southern Appalachian region belong to the same metallogenetic epoch. While it is not improbable that this is true, it has not, as yet, been established by sufficient detailed geological work. Many of the older geologists considered the veins contemporaneous with the enclosing rocks which were classified as "primary." Becker and most of the recent workers have placed the deposits in the pre-Cambrian.

The veins in the district covered by the present report, were formed after the intrusion of the granite, and probably represent the final stage in the period of igneous activity which preceded their deposition. They show no evidence of having been subjected to the great crustal movements which so intensely metamorphosed the enclosing sedimentary rocks and even the massive granites. These movements were probably inaugurated and the sedimentaries rendered schistose prior to the intrusion of the granites with which they are in contact. The well-developed schistosity of most of the granitic rocks is evidence that the movements continued throughout the greater part of the period covered by their intrusion. The porphyritic facies of the granite show decreasing pressure effects and many of the pegmatites are practically massive. These facts are discussed at greater length in the chapter on structure and metamorphism.

The profound changes to which the ore-bearing formations were subjected prior to the intrusion of the granite, indicate that a considerable time interval must have intervened between the deposition of the sedi-

ments and the formation of the veins; and this together with the lack of important crushing, or other evidence of disturbance in the quartz veins, suggests that they are later than pre-Cambrian in age.

Subsequent to the intrusion of the granite and the formation of the gold veins, sufficient time elapsed for erosion to remove the overlying material and expose the deep-seated granite, before the surface was again depressed to receive the sediments of late Ordovician time. The Arvonian slates, which are known to be Cincinnatian in age, were laid down on the older schists and in places on granite which is only slightly schistose. Therefore even the granites which were last to solidify are older than Cincinnatian in age. The slight evidence of dynamic metamorphism exhibited by the gold-bearing veins was probably induced by the movements which elevated and folded the Ordovician sediments.

A consideration of the facts outlined above makes it appear reasonably certain that the primary gold deposits in the James River basin are older than Cincinnatian in age, and they are probably younger than pre-Cambrian. Until further evidence is available, the writer is of the opinion that the veins should be classified as Cambrian.

CHAPTER VII.

PLACERS.

Gold has been found in the gravels of all streams that cross the gold-bearing rocks of this area, and also in certain ancient stream gravels that are now located high above the neighboring water-courses. Most of these "branch" gravels, as they are locally called, have been worked, and some of them reworked a second time in order to recover the precious metal which they contained. Gold also occurs, concentrated in considerable quantity, in the accumulations of residual decay overlying the gold-bearing veins and in their immediate vicinity, and such deposits have been profitably worked in a number of places.

When the gold-bearing veins and the enclosing country rocks were exposed by denudation to the chemical and mechanical action of the agents of erosion, the slow process of concentrating the heavier and more resistant constituents into the placer deposits began, and this has been in continuous operation ever since. The minerals with least resistance are attacked first, their decomposition making easier the disintegration of the remainder, and under this process the rocks slowly go to pieces. If the products of weathering collect faster than the streams can transport them, deep residual soils are gradually formed. Of the common minerals, quartz is the hardest, the least soluble, and does not undergo chemical decomposition; and since it is the principal vein-forming mineral, the veins usually extend for some distance above hard rock into the overlying mantle of residual decay, but frost and plant roots step by step break up even the larger veins and add their constituents to the soil.

With the breaking down of the rocks and the formation of disintegrated material, the next step in the process of concentration is that of sorting and transportation. Expansion and contraction, due to changes in temperature and to freezing and thawing where water is present, cause the soils to gradually creep down hill. The wash of rain water aids in this slow movement by carrying off the lighter particles, while the heavier fragments lag behind. In this way a partial concentration of the heavier constituents in the residual decay is brought about, and as gold has a very high density and is relatively insoluble, it frequently occurs in considerable quantity in the decomposed material lying vertically above gold-bearing veins, and along the hill slopes immediately below them. The gold found

in such localities has not traveled far and is therefore comparatively rough and angular, while the quartz and other rock fragments which may accompany it do not show the rounded waterworn surfaces of stream gravel. Deposits of this nature have been worked in a number of places, notably at the Tellurium and Waller mines where they are said to have been very rich.

The slow creep of the soil and occasional heavy rains gradually bring the products of disintegration within reach of running streams, which continue the work of concentration, but here an additional process is brought into play—that of abrasion. The swiftly flowing streams rapidly remove the finer sediments in suspension while the heavier fragments are rolled along more slowly by the current, constantly striking and grinding against one another. This continual impact and friction, in time, is sufficient to wear away the toughest rocks, and quartz while hard is rather brittle. The gold, being malleable, escapes most of this comminution, and because of its high specific gravity settles through the sand and gravel until it finds lodgment close to bedrock. In this manner the placer deposits are gradually formed in the stream beds.

If for any cause the course of a stream is changed, the placer gravels which have been formed in its bed may remain as deposits of dry gravel which, as the stream deepens its channel, are left high above the water level. Placer gravels of this type were at one time extensively worked on the Collins place, a mile northeast of Lantana.

As a result of the hammering which they have undergone, the gold nuggets found in placer deposits are smooth and rounded, differing in this respect from those found closer to the original vein deposits. The placer gold is, moreover, somewhat purer or of a higher degree of fineness than the vein gold, for during the long time in which it has been subjected to the oxidizing and solvent action of the agents of weathering, impurities have been largely removed. In other words, the gold has passed through a sort of natural refining process as well as one of concentration.

The unusual richness of the branch gravels as compared with the original vein deposits from which they were derived is due to the great length of time in which the process of concentration has been going on, the large amount of material which has been worked over, and the very limited extent of the gold-bearing gravels formed.

The area has probably been subjected to erosion almost continuously since the close of Ordovician times, and this has affected the gold deposits ever since the veins were first exposed by degradation. Everything bearing

on the genesis of the gold veins, as has been stated in detail elsewhere, indicates that the portions of the veins that are now exposed, were formed at a great depth below the surface; and a study of the physiography of the area gives independent evidence as to the thousands of feet of overlying rock removed by erosion. The veins, when formed, must have extended several thousand feet above the present surface, and while most of the gold originally contained in this vast amount of material was probably carried away and lost, a considerable proportion of the metal, because of its toughness, resistance to ordinary solvents, and high specific gravity, has been retained and concentrated into the relatively small bulk of material composing the placer gravel deposits.

The placer gravels of Virginia are limited to the immediate vicinity of the vein-deposits from which they have been derived, and nowhere do they cover large areas, being almost entirely confined to the branches and smaller creeks. Much of the placer gold is coarse, and this together with its comparative roughness indicates that it has not traveled far. The branches are frequently reported to have been richest near the veins, and none of them was worked for any great distance below the lowest known veins, usually less than a mile. They carried little or no value above the veins, and in fact many of the veins, which seldom outcrop, were located by panning up the branches. Large deposits of low-grade gravels, such as those in California which were extensively worked at one time by hydraulic methods and are now being worked by dredging, have not been found in Virginia. The only place within the present area where it would be possible to find similar gravels is in the Triassic beds, which are exposed near the southern boundary of the area. It is interesting to note that Becker, working in a similar district, found transported gold in the Newark (Triassic) conglomerates of North Carolina.^a

During the time in which the present branch gravels were being concentrated, the physiographic conditions in Virginia were not suitable for the formation of low-grade placers. The fact that approximate peneplanation has continued for a long period of time is probably the reason that large deposits of auriferous gravels are absent and that the placer gravels are all concentrated close to the primary deposits. The factors which make the Virginia branches such perfect "concentrators" having been outlined above, it might be of interest, for purposes of comparison, to state briefly the conditions under which the large low-grade deposits of California were formed.

^aBecker, Geo. F., *Reconnaissance of the Gold Fields of the Southern Appalachians*, 16th Ann. Rept., U. S. Geol. Survey, 1894, pt. iii, pp. 315-316.

In California the mountain streams crossing the gold area are swift, and consequently their powers of transportation high; the rainfall is light, but largely confined to certain seasons of the year when sudden floods are not uncommon. The result of these conditions is to give a maximum of transportation efficiency for a given volume of water, and the streams are able to carry down vast quantities of gravel and even boulders of considerable size. When the streams, however, reach lower elevations and enter the large valleys that stretch back from the coast, their velocity is checked and their power of transportation suddenly diminished, causing them to drop a large part of their load. In this way gravel deposits, which often cover large areas to a depth of 30 or even 100 feet or more, and which in places contain small quantities of irregularly distributed gold, have been built up in some of the valleys.

The placer gravels were extensively worked during the early days of mining in the James River district, and in many places they are reported to have been very rich. At this late date no authentic records are obtainable that would give the amount of gold produced by the placer deposits of this district, or even of the State as a whole, but it is unquestionable that a very large percentage of the total gold production in Virginia has been derived from the gold-bearing gravels. While most of these branch gravels were worked out years ago, it is still possible to estimate the extent of the deposits from the irregular piles of gravel that were always left behind.

In this section all known placer deposits that could be profitably worked by the simple methods formerly employed, were long ago exhausted, and it is improbable that new ones will be discovered in the future. In regions, such as this, which have long been inhabited, one can no longer expect to find rich, easily workable placer gravels, and this is especially true in a section where the presence of gold has been known for so many years, and where so much prospecting has been carried on. The presence of gold in such deposits is so easily detected, even by those with little experience, that there is little likelihood of its being overlooked, and the methods that may be used to recover it are so simple and inexpensive that the deposits are quickly worked out.

Much gold was lost by the wasteful methods commonly employed when the branch gravels were first worked, and it would probably pay to rework many of these deposits, if a suitable method could be devised for handling them cheaply on a large scale. In the early days of mining the branches were usually leased, and the gravel washed in rockers by tributers who

paid a certain percentage of the gross proceeds, as a rule a fifth of the gold recovered. Some gold escaped recovery or was overlooked, and when the gravels were poor or mixed with sufficient clay to make washing difficult they were left untouched. Panning shows considerable gold even in the gravels that have been washed, and these also contain some mercury and amalgam lost by the early miners. Most of this gold is fine but it is granular and easy to recover; the gravel is small in size, contains but little sand and there are no boulders. In most places the grade is not sufficient for sluices.

The only known placer gravels which have not been worked are those that occupy the bed of Byrd Creek and in places underlie the adjacent lowlands, but up to this time the difficulties involved in the profitable handling of these gravels have proved insurmountable. While they have not been systematically prospected, it seems certain that the Byrd Creek placer gravels must contain much gold. Byrd Creek is one of the larger streams of the area, and it cuts directly across the gold belt, while its tributaries include most of the rich branches formerly worked for gold.

So far as known the only effort to work the Byrd Creek gravels was made about the year 1900. During the summer, while the water was low, an attempt was made just above Bowles' Bridge, 4 miles northeast of Columbia, to turn the creek aside, sink pits down to bedrock in the stream bed, and wash the gravel in rockers, but this experiment proved unsuccessful, for the water could not be kept out and the pits soon caved. It is said that the gravel was about 7 feet deep and that there was no overburden of mud; bedrock looked like slate and was covered with a layer of soft, decomposed rock that made shoveling easy. The gold was coarse, most of it being "about the size of wheat grains." The conditions may have been unusually favorable at this place as a branch that had rich placer gravels entered the creek not far above.

The only other information bearing on the value of the Byrd Creek gravels is furnished by some prospecting done on the Bertha and Edith tract, which lies on the east side of the creek 3 miles northeast of Columbia. All the branch gravels on this place were washed for gold years ago, and the placers along Great Camp and Maple branches are reported to have been very rich. At that time Big Byrd Creek was dammed to furnish power for a mill located near the southern end of the property, and the mill pond thus formed covered about 3 acres including the lower portions of Great Camp and Little Camp branches. The gravels covered by the old mill pond, which has since been drained, have never been worked. In

1897, a company, which held the property under lease and option, sank a number of prospect pits in the flat near the mouth of Great Camp Branch and started to work the deposits, but all work was discontinued when their nearly completed mill and cyanide plant were destroyed by fire. Where the prospect pits were sunk the gravel was found to be from 1 to 2½ feet thick and covered with an overburden of from 4 to 7 feet of sandy soil. It is stated that all the gravel carried gold, the values averaging from 1 to 2 pennyweight per square foot. The amount of gold did not seem to vary with the thickness of the gravel and most of it was found close to bedrock. The gold was quite coarse, many of the grains weighing from 0.10 to 0.20 pennyweight, while the largest nugget recovered weighed 1.78 pennyweight.

These facts prove that coarse gold was carried by the branches as far as the creek, and it can hardly be doubted that the gravels of the creek bed contain sufficient gold to make their mining profitable, providing a suitable method of handling them can be devised.

Any successful method of working these placer gravels will have to take into consideration the following facts:

(1) Along much of its course Byrd Creek is bordered by steep banks, which in places give way to high bluffs, and this would make its diversion difficult if not impracticable.

(2) The mean discharge of the stream is large and it is subject to occasional floods.

(3) There is not sufficient fall in the creek to allow the employment of sluices, and the disposal of tailings would be difficult.

(4) While no boulders occur in these gravels, the banks are in many places lined with trees, and their roots would probably interfere with dredging or similar methods of mining.

(5) At several points there are rapids in the creek caused by ledges of resistant rock which outcrop in the bed of the stream.

CHAPTER VIII.

DESCRIPTION OF COPPER MINES AND PROSPECTS.

TYPES OF COPPER DEPOSITS.

Copper ores have been prospected at three localities in this district and the ore-deposits consist of two distinct types. The Lightfoot mine on the southeast side of Slate River about 2 miles northwest of Arvonja, and the Anaconda mine, located $3\frac{1}{2}$ miles west of Johnson and 5 miles north of Dillwyn, belong to one type, while the mines near New Canton are opened in a very different kind of ore-deposit.

Ores of the type first mentioned occur as veins or lenticular masses in greenstone schists derived from basic igneous rocks, while ores of the last-named type are found impregnating crystalline schists, adjacent to their contact with an intrusive granite (quartz-monzonite with a dioritic border facies). In both types the principal ore-minerals are pyrite, more or less auriferous, and chalcopyrite. The origin of the ores belonging to each type will be discussed after the individual occurrences have been described.

DESCRIPTION OF INDIVIDUAL MINES.

The Lightfoot Mine.

Location.—The Lightfoot copper mine is located on the southeast side of Slate River, 2 miles northwest of Arvonja.

History.—The property was first worked for gold (see p. 207), but the copper deposit was opened shortly before the war by a company which is said to have shipped 100 tons of the ore to a smelting house in Baltimore, where it brought \$80 per ton.^a The outbreak of the war in 1861 put a stop to work at the mine, and since that time while there have been some spasmodic attempts to develop the property (the last about 1904) little has come of them. A shaft has been sunk to a depth of 85 feet, the collar of the shaft being about 20 feet above the level of the nearby stream, and several short drives have been opened.

Country rock.—The Lightfoot mine is situated in an area of greenstone schists, which under the microscope are seen to be igneous in origin. The strike of the schistosity is northeast and southwest and the dip is steeply

^aHamilton, J. R., The Natural Wealth of Virginia, *Harper's Magazine*, 1865, vol. xxxii, p. 41.

toward the northwest. The schists show little variation in texture or color, being usually dark green and fine-grained. Megascopically, chlorite and epidote with occasional eyes and stringers of quartz and calcite are the most prominent minerals; and when the powdered rock is tested with a magnet it is found to contain an abundance of fine-grained magnetite. In addition to these minerals, plagioclase feldspars, hornblende and some titanium minerals can usually be recognized under the microscope. These rocks are described in greater detail on pages 49-51. A little pyrite, often more or less cupriferous, and the secondary copper mineral—malachite—were found in the schist at several places within a mile or less of the mine. Where the rocks have been much fractured the openings are filled with quartz, epidote, calcite, or mixtures of these, forming irregular veinlets. In places magnetite appears to have undergone a similar concentration and may be picked up on the surface in pieces the size of hen's eggs or even larger.

Ore-deposit.—According to Credner, the vein was 4 to 5 feet wide near the surface, and consisted of iron oxide; below this capping, iron pyrites was encountered and continued for about 20 feet before chalcopyrite began to appear; and in the lower workings he found a coarse-grained mixture of iron and copper sulphides, which carried 11 per cent. copper.^a The lower workings of the present opening are said to show an irregular vein, which in places consists of roughly parallel veinlets, ranging from several feet in width down to an inch or less, and the walls are rather sharply defined.

The waste rock found on the dump shows that the country rock in the immediate vicinity of the vein has been greatly crushed and fractured. Extensive epidotization has taken place along the fractures, and where openings had been formed they are usually filled with quartz containing crystals of epidote and sometimes considerable calcite. The veinlets formed in this way are usually 4 or 5 inches in width or less. In places vug-like openings occur lined with quartz and crystals of epidote. Pyrite and chalcopyrite are occasionally present in the wall rock as well as in the veinlets, and where these minerals have been long subjected to oxidation the green stain of malachite is usually prominent. All the rock contains more or less magnetite, and fine-grained masses of this mineral, weighing several pounds, were noted, in which the only impurities that could be detected megascopically, were a little quartz, epidote, and occasionally

^aCredner, H., Report of Explorations on the Gold Fields of Virginia and North Carolina, Amer. Jour. Mng., 1869, vol. vii, p. 58.

chalcopyrite. A piece of the greenstone schist found on the dump contained a veinlet or segregated area of white feldspars, which were 0.5 to 1 cm. in diameter, and showed fine albite twinning. Chalcopyrite and magnetite were plentifully distributed between the feldspars, and in places along their cleavage planes, in a way that indicated a later origin for the ore minerals.

The best ore seen at the mine consisted essentially of a mixture of pyrite and chalcopyrite, but most of the ore found on the dump was composed chiefly of pyrite, slightly cupriferous, with a little quartz, chlorite, and epidote visible to the naked eye. Assays of the ore are said to show good values in gold, and Hamilton states that native copper was found in some of the ore, but this could not be confirmed.

The Bumpus Property.

At several other localities in this vicinity a little prospecting for copper has been carried on. The old Bumpus place lies northwest of the Lightfoot mine on the opposite side of Slate River, and here a 20-foot shaft was sunk at a point where much limonite and magnetite were found on the surface. The shaft was opened in soft chloritic slate, and no copper ore seems to have been found.

The Ford Property.

On the Ford property, about three-quarters of a mile southwest of the Lightfoot mine, a vein is said to have been discovered in 1835, which was rich in gold at the surface, but at a depth of 4 or 5 feet copper pyrite became so plentiful as to interfere with amalgamation, and the work was abandoned.^a Later, a 60-foot shaft was sunk to strike the vein at another point, but a few lenticular quartz concretions containing copper pyrite seem to be all that was found. Credner mentions two small veins that were exposed by open cuts, the gangue being quartz, while iron and copper pyrite, and a little free-gold were present.^b

The Anaconda Mine.

Location.—The Anaconda mine is located near Eldridge Mill, and is about $3\frac{1}{2}$ miles west of Johnson and 5 miles north of Dillwyn, stations on the Buckingham Branch of the Chesapeake and Ohio Railway.

History.—The Anaconda mine was formerly known as the Eldridge mine, and about 1903 it was under development by the Q. Q. Copper Co.,

^aHamilton, J. R., Op. cit.

^bCredner, H., Op. cit.

which sank a shaft to a depth of approximately 60 feet. About 1905 the United States Mineral Co. did a little development work, and in 1910 the shaft was again pumped out, but almost immediately allowed to refill with water. The shaft is now said to have a depth of nearly 75 feet, and near the bottom, a short drive extends in a northeast direction. While work was going on, 3,300 pounds of ore running $10\frac{3}{4}$ per cent. copper were shipped to the smelter at Norfolk.

Descriptive geology.—The ore-deposit lies in the same belt of greenstone schists in which the Lightfoot mine is located and the country rocks are, for the most part, similar to those already described. About 400 yards northeast of the mine several openings have been made exposing amphibole asbestos, some of the fiber being 7 or 8 inches in length, talc, and chloritic schists carrying needle-like crystals of actinolite. The rock found on the dump is practically the same as that at the Lightfoot mine. It is mostly a dark green, fine-grained chloritic schist, in which considerable epidote is present especially along fractures. A little calcite in small crystals is in places scattered through the rock mass, but no veinlets or large masses were seen. Fine-grained magnetite and occasional grains of pyrite and chalcopyrite were noted. In a thin section (Spec. 352) the minerals present, in the order of their relative abundance, are quartz, chlorite, epidote and zoisite, hornblende, calcite, plagioclase feldspar, pyrite, and titanite. The hornblende occurs in dark green, needle-like prisms largely altered to chlorite. The calcite frequently shows multiple twinning. It is apparently a basic igneous rock which has been extensively altered by pressure and hydrometamorphism.

Specimens of the ore seen at the mine consist essentially of pyrite and chalcopyrite intercrystallized with quartz as gangue. A little bornite, probably secondary, was noted in places, and the carbonates azurite and malachite, derived from the sulphides, are also present, usually along fractures in the rock. The vein is said to be several feet wide in places, but elsewhere pinches to almost nothing.

Genesis of Ores at the Lightfoot and Anaconda Mines.

Many basic igneous rocks in different parts of the world have been found to contain small quantities of copper. Rocks of this type are common throughout much of the Blue Ridge region in Maryland and Virginia where there are basaltic lava flows, which, since their extrusion, have been greatly altered, with the production of secondary minerals, especially chlorite and epidote. As a result of the metamorphic changes

which these rocks have undergone, the small amount of copper originally disseminated in the rock has, in places, been locally concentrated along joints and fractures, giving rise to copper deposits which have become known as the Blue Ridge or Catoctin type.^a

The ores at the Lightfoot and Anaconda mines are similarly situated in an area of altered basic rocks, igneous in origin; and copper-bearing minerals have been found occurring in the country rock in small quantities at a number of widely separated localities; but there is a marked difference between the ore-deposits in this area and those of the Blue Ridge type, especially in the character of the ore-minerals. In the Blue Ridge type of deposit, the ore-minerals are chiefly cuprite and native copper, the latter often as nucleal masses surrounded by cuprite, together with small amounts of azurite and malachite, and, very rarely, of copper sulphide.^b At the Buckingham County mines the copper minerals are chiefly sulphides, malachite and azurite being present only to a limited extent, and where they have been clearly derived from the sulphides, while cuprite and native copper are rare if they occur at all.

Both the Lightfoot and the Anaconda mines were inaccessible when the writer visited the district in 1910, and it would be impossible to make definite statements in regard to the genesis of the ore-deposits without more detailed examination, but it seems probable that the copper, which they contain, was originally disseminated through the surrounding rocks, and that it has been concentrated by the circulation of meteoric waters, at favorable points in openings formed by local fracturing. Some of the principal facts in favor of this hypothesis may be summed up as follows:

(1) Copper-bearing minerals are present in small quantities in the country rock at considerable distances from the ore-deposits, and therefore the country rock furnishes a possible if not the probable source of the ore-minerals.

(2) The principal gangue minerals in the ore-deposits—quartz, epidote, calcite, and magnetite—are important constituents of the country rock, the difference being one of relative proportions only, and no minerals have been observed in the ores that have not been found in the country rock. Therefore the country rock furnishes a possible if not the probable source of the gangue minerals.

^aWeed, W. H., Types of Copper Deposits in the Southern United States, Trans. Amer. Inst. Min. Eng., 1900, vol. xxx, p. 498.

^bWeed, W. H., Copper Deposits of the Appalachian States, U. S. Geol. Survey, Bull. No. 455, p. 14.

(3) The fracturing of the rocks furnished a channel for the circulation of concentrating solutions and openings for the deposition of the ore-deposits.

(4) The extensive formation of hydrous from anhydrous minerals, which is the chief feature in the metamorphism of the great mass of rocks in this immediate area, necessitates the introduction of much water, and circulating water is an agent sufficient to account for the transportation and concentration of the minerals forming the ore-deposits.

(5) The extensive formation of epidote adjacent to fractures in the immediate vicinity of the ore-deposits is evidence of the circulation of solutions at these points.

The difference between the Buckingham copper deposits and those of the Blue Ridge type may possibly be due to the formation of the former at a greater depth, and to the fact that the greenstone schists in this district are, as a whole, more dense, closer textured and without the amygdaloidal cavities and similar openings common in much of the Catoctin schist. As originally deposited, these ores probably consisted chiefly of cupriferous pyrite, and in that case most of the chalcopyrite owes its origin to secondary enrichment. It is doubtful whether the copper values will continue to any considerable depth from the surface, and the writer does not believe that these deposits will prove to be very extensive or of much economic value.

THE NEW CANTON MINES.

The New Canton ore-body has been exposed by a series of openings, consisting chiefly of shafts and tunnels, which begin at a point half a mile south of New Canton and extend in a straight line for a distance of a mile in a southwesterly direction. (See map, fig. 2, p. 17.)

HISTORY.

While the New Canton mines have never been of much economic importance, they have had a long and varied history, having been first worked for iron, later for copper, and more recently prospected for pyrite. The gossan or oxidized ore, which consists principally of limonite and forms the surface cap of the sulphide bodies, first attracted attention; and according to Prof. Rogers, iron was manufactured from the Buckingham ore as early as the Revolutionary War. However, very little mining was done until some time in the early 30's, when a charcoal furnace, known as the Bear Garden or Dean furnace, was built about half a mile south of New Canton. In his "Report of the Geological Reconnaissance of the

State of Virginia, 1835," Rogers states that, "the limestone on the western edge of the county furnishes the flux employed in the smelting of this ore, which, under the superintendence of Mr. Dean of New Canton, is now conducted on a scale of such extent as to give a weekly product of between thirty and forty tons of pig metal, much of which is of a superior quality."^a Piles of slag indicate that there was another furnace located less than a mile southwest of New Canton. Mining was entirely confined to surface cuts along the outcrop, and as these became deeper pyrite began to appear and rapidly increased until the percentage of sulphur became prohibitive. Rogers says that fine specks of gold were discovered in the cinder or slag at these works. Iron ore was also hauled from Ore Bank, three-quarters of a mile southeast of Arvonias, and smelted at the New Canton furnace, but in 1840 the furnace was abandoned and no further work seems to have been done until prospecting for copper was started.

The Johnson Mine.

At the Johnson mine, formerly known as the Staples mine, which is located three-quarters of a mile west of south from New Canton, a 78-foot shaft was sunk by Mr. Staples, who mined and shipped 780 tons of ore averaging 8 per cent. copper. After this the property was leased and operated by White & Walters for a period of 2 or 3 years, beginning about 1891. Several shipments were made and \$4,000 is said to have been realized from the copper in the ore. About 1903, the Johnson Mining Co. bought the property and began development work. A vertical shaft, started on top of the hill, was sunk to a depth of 278 feet, and an adit was driven from the creek northwest to connect with the shaft. There are 3 levels in the mine and the total length of the drives is said to be 1,000 feet or more, but little or no mining was done.

The McKenna Mine.

The McKenna mine joins the Johnson mine on the northeast, and is situated a little over half a mile south of New Canton. It was first prospected for copper by J. P. McKenna about 1895, and in 1906 the Virginia Copper Co. began to develop the property. A 53-foot shaft was sunk at the foot of the hill in the lowlands near the creek, and two short drives opened from it, but work was stopped in 1907, and has not been resumed since that time.

^aRogers, W. B., *Geology of the Virginias*, p. 80.

The Hudgins Mine.

The Hudgins mine, located 1.5 miles southwest of New Canton, was opened about the same time that the other two mines were being prospected. A shaft was sunk to a depth of about 70 feet, which seems to have been the extent of the development work. When visited by the writer in 1911 the shaft had partly caved and was inaccessible.

The Margaret Mine.

The Margaret or Terrell mine adjoins the McKenna mine and is situated on the west side of Phelps Creek about half a mile south of New Canton. This property was first opened in April of 1910, when a shaft was sunk to a depth of 80 or 90 feet in search of a pyrite deposit that could be profitably worked. When examined by the writer in the summer of 1911 the shaft had been pumped out, and preparations were being made to sink it deeper.

GENERAL DESCRIPTION OF THE GEOLOGY.

The bluffs along James River and Phelps Creek furnish an almost perfect section across the rock strata in which the New Canton mines are situated, and this section, together with the mine openings and occasional outcrops elsewhere in the vicinity, make it possible to study these ore-deposits in somewhat greater detail than can be done in the case of most of the veins that occur in this area.

The New Canton sulphide deposits occur in a schist, sedimentary in origin, which, a few hundred yards west of the mines, is interbedded with a schistose quartzite. East of the mines, stretches the area of intrusive granite (chiefly granodiorite), but between the granite and the ore-deposits is a belt of hornblendic schists 700 to 900 yards wide, part of which represents a basic border facies of the granite, while the rest is probably sedimentary in origin, though intensely metamorphosed by the intrusion of the great igneous magma. It is not possible to draw with certainty a line between the hornblende schists that are igneous, and those that are chiefly sedimentary in origin, for the former as well as the latter have been greatly changed by metamorphism under mass-mechanical conditions; and the difficulty is increased by the fact that there are dikes or apophyses from the igneous mass, interleaved with metamorphic rocks which are apparently sedimentary in origin. The series of rocks encountered in passing across this contact is described in detail on pages 107-112, and therefore they will be discussed here only in so far as it is necessary to bring out their relations to the ore-deposits.

Northeast of the mines, at a distance of 300 to 400 yards, the country rock is a dark gray knotted slate, or schist, containing numerous rounded pseudophenocrysts of biotite averaging 1 to 1.5 mm. in diameter. These crystals of biotite are dark brown to black in color and have no regular orientation relative to the schistosity of the fine-grained slaty ground-mass in which they are embedded. Small reddish-brown garnets may also be present but are not plentiful. In the ground-mass quartz, sericite, and a few scattered grains of magnetite, are the only minerals distinguishable megascopically, but under the microscope biotite, chlorite, and rarely plagioclase feldspar, may also be identified.

Passing eastward toward the contact, the biotite crystals gradually give place to garnets, and at the same time the schists become slightly coarser grained and lighter in color. The difference in color may be due to difference in composition, but is probably, in part, caused by increased development of sericite and a greater concentration of the iron in certain iron-bearing minerals. Small crystals of pyrite are abundant in the schists near the ore-bodies, which have no definite walls or boundaries. The ore is found in white to light gray, garnetiferous schists which, aside from the impregnating pyrite, are composed essentially of sericite and quartz, though chlorite is usually present and sometimes in considerable quantity. Plagioclase feldspar occurs to a limited extent, and occasional crystals of hornblende begin to make their appearance.

The ore-minerals, chiefly pyrite, occur irregularly disseminated through the quartz-sericite schist, and where most abundant form irregular stringers or lenses parallel to the schistosity. The mineralized schists are cut by occasional small lenticular veins of quartz, carrying more or less feldspar, but as a rule they contain little pyrite, though the latter, in places, is concentrated along the walls of the veins.

The hornblende schists on the east side of the ore-bodies are usually fine-grained but vary somewhat in composition and texture in passing across their strike. In the vicinity of the ore-deposits, and for some distance along their line of strike where they have not been found, there is usually much pyrite in the hornblende schists. Within 100 or 150 yards of the ore-bearing schists, apophyses of the granite occur as intrusions in the hornblendic rocks, and, at least in places, there is a narrow band along their contacts composed essentially of chlorite and garnets. The line drawn on the map (fig. 2) to represent the approximate contact between the rocks that are igneous and those that are sedimentary in origin, is located on the basis of the structural relations and appearance of the rocks

in the field, rather than on any difference in texture or mineral composition, and while it is unlikely that there are important masses of altered sedimentary rocks on the east side of the line, there are known to be apophyses or dikes on the west of it. Much vein quartz occurs as small pieces in the soil derived from the sedimentary schists in the vicinity of their contact with the area of igneous rocks on the east.

The ore-body is apparently continuous for a distance of more than a mile along its course. It is not exposed in the section furnished by the bluffs along Phelps Creek, although near the line of its strike much pyrite is present in the schists. Southwest of the Hudgins mine, outcrops are not as plentiful, and it is impossible to say how much farther the ore-body extends in that direction. A little prospecting is reported at several places, but nothing of value has been discovered.

DETAILED DESCRIPTION OF THE ORE AND INCLOSING ROCK.

The Margaret Mine.

The outcrops of the ore-bearing rocks are stained with limonite and more or less porous from the oxidation of sulphides. In places directly above the ore-body there are large outcrops of gossan, consisting of dark brown, porous limonite containing comparatively little silica, and only occasional fragments of decomposed schist. At the Margaret mine, the dark bluish-gray schist with phenocrysts of garnet and biotite occur less than 100 feet west of the shaft started in the limonite capping, and pieces of hornblende schist were found lying on the surface only a short distance toward the east. Intermingled with the hornblende schist were found a few pieces of fine-grained quartzite, carrying irregular dark green crystals of hornblende and light greenish-brown needles of sillimanite. Pieces of rock were also found which appear to be intermediate in mineral composition between the hornblende schists and the quartz-sericite-chlorite schists.

The shaft at the Margaret mine was sunk on top of a ridge about 30 to 40 feet above the creek and the limonite ores continued to a depth of 28 or 30 feet, which is approximately the water level, before pyrite was encountered. Pyrite more or less cupriferous is the chief ore-mineral from this point down, but at a depth of about 55 feet it is accompanied by some chalcopyrite and bornite. The copper sulphides are not very plentiful and seem to be confined to a zone having a vertical thickness of 4 or 5 feet. In the bottom of the shaft which is about 90 feet deep, pyrite, slightly cupriferous, is the only ore-mineral. Fractures or joints in the rocks are frequently coated with hyalite, usually white but some-

times light green from copper stain. The strike of the schistosity is about N. 30° E. and the dip practically vertical. All the schists exposed in the shaft are more or less impregnated with sulphides, but the distribution is very irregular, the areas of greatest concentration frequently having the appearance of veinlets of pyrite. The schists are cut by occasional small lenticular veins of quartz and feldspar ranging up to 5 or 6 inches in width. The sketch shown in fig. 23 roughly illustrates the structural relations of the ore-deposit and the distribution of the pyrite.

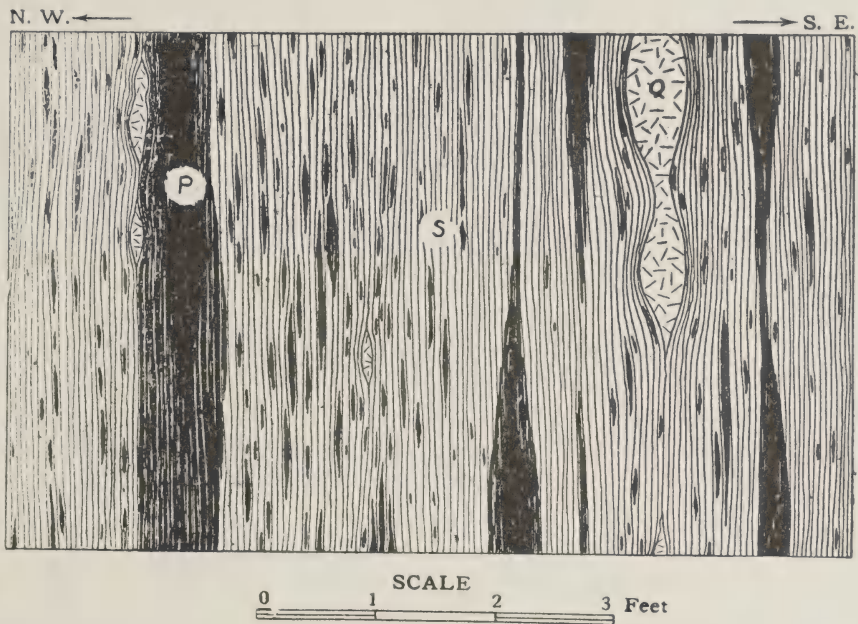


Fig. 23.—Diagrammatic section showing quartz-feldspar lenses and distribution of sulphides in schist at the Margaret Mine. *Q*, quartz-feldspar lens; *S*, schist with a little disseminated pyrite; *P*, chiefly pyrite.

The richest ore consists of 80 or 90 per cent. pyrite, a little white sericite, scattered pink garnets 1 to 1.5 mm. in diameter, a few small flakes of chlorite, and a little quartz. A thin section for microscopic examination was made from a piece of schist (Spec. 312-C) carrying about 60 per cent. pyrite. In the hand specimens the rock appears to consist almost wholly of slightly cupriferous granular pyrite (1.5 to 2 mm. in diameter) and white sericite, with only a few small pink garnets. The distribution of the sulphides is closely related to the schistosity of the rock.

Near joint planes the sulphides have a dark coating and the white sericite is stained green by the presence of a small amount of copper. Under the microscope the smaller crystals of pyrite frequently show cubical form, but the larger masses have irregular outlines. The sericite is mostly oriented parallel to the schistosity, but many of the flakes look as though they had been pushed aside by the pyrite. Quartz is more plentiful in the thin section than one would suppose from a megascopic examination of the rock. It shows marked optical distortion and slight granulation from crushing, and contains occasional liquid and gaseous inclusions. A little magnetite is present in small grains and is usually closely associated with pyrite.

Another specimen (316) of schist, showing the contact with a quartz-feldspar stringer which cuts across the cleavage and has narrow veinlets of quartz branching off parallel to the schistosity, is a light gray, close-textured rock composed of fine-grained quartz, sericite, chlorite, a little magnetite, and numerous red garnets ranging up to 1 mm. in diameter. Pyrite is plentiful but not abundant, occurring in grains and small lenticular masses elongated in the direction of schistosity; and while disseminated throughout the rock appears to be slightly more concentrated near the quartz veinlets. Under the microscope the quartz grains show irregular interpenetrating outlines and wavy extinction. The flakes of sericite and most of the light green chlorite are oriented parallel to the schistosity. The garnets are very ragged in outline and micropoikilitic in texture from numerous inclusions of quartz. In places they show slight alteration to chlorite. Plagioclase feldspars are also present and the minerals magnetite and pyrite are plentiful, frequently showing a close association, with pyrite occurring as inclusions in the magnetite or with the latter surrounded by the former.

The quartz-feldspar veinlets range up to 6 inches or more in width, and are composed essentially of coarsely crystalline quartz, varying from white and translucent to clear and glassy, with more or less feldspar in angular crystals, having sharp straight outlines, ranging up to 1 cm. or over in diameter, and white to light yellow in color. In portions of the veinlets feldspar constitutes 10 per cent. or more of the mass while elsewhere it is practically absent. The feldspar crystals occur throughout the vein but are more plentiful near the walls and in places extend for a fraction of 1 cm. into the enclosing schists. Small masses of chlorite and garnet, probably representing inclusions of the country rock, are occasionally present. A little pyrite occurs in the central portions of the veinlets,

usually along cleavage planes or contacts between feldspar and quartz, but most of it is found near the walls and is yet more abundant in the enclosing schists. In thin section (315) under the microscope, the quartz shows some granulation and marked undulatory extinction, but the feldspars, aside from a slight warping of the cleavage planes, which is visible in the hand specimen, show no pressure effects. The feldspar is a soda-lime plagioclase, chiefly oligoclase-andesine, and usually shows multiple twinning after the albite law, though this appears to be absent in places.^a Liquid and gas inclusions, usually arranged in rows or planes, are plentiful in the quartz and occur to a lesser extent in the feldspar.

The McKenna Mine.

At the McKenna mine the gossan is exposed in the side of the hill just above the shaft, and apparently grades into the enclosing schists. It is said to be only about 8 feet deep in the shaft, which is located not far from the creek and fills with water almost to the surface. Descriptions of the ore-body exposed by the underground workings, and the rock lying on the dump, indicate that the deposit is similar in every way to that at the Margaret mine. It is reported that "peacock" copper ore was struck in the shaft about 35 feet from the surface, where it was about 8 feet wide and 6 feet thick. The walls of this secondary copper deposit were fairly well defined, but the large masses of pyrite graded into the country rock without definite walls.

A specimen obtained by Dr. Maynard from the bottom of the shaft, 53 feet from the surface, is darker colored and more chloritic than most of the rock found on the dump or in this vicinity. It is a dark green foliated schist in which chlorite, quartz, biotite, garnet, pyrite, and magnetite are easily distinguished megascopically. In thin section (Spec. 6) plagioclase feldspars can be identified, but as they closely resemble the quartz in index of refraction and do not always show twinning, it is impossible to estimate their relative abundance, though the quartz is probably much in excess. Part of the chlorite gives evidence of its derivation from biotite. A little sericite is also to be seen and a few light brown prismatic crystals, probably of hornblende. Pyrite is abundant and magnetite plentiful, the two minerals being closely associated, with pyrite usually surrounding the magnetite.

^aA specimen of this feldspar was submitted to Dr. E. S. Larsen, Jr., for determination by the immersion method. He identified the feldspars as albite-oligoclase to oligoclase-andesine and states that the fresh and dominant feldspar is oligoclase-andesine. The maximum and minimum indices of refraction are:

$$\begin{aligned}\alpha &= 1.535 \pm 0.003 \text{ to } 1.541 \pm 0.003 \\ \gamma &= 1.542 \pm 0.003 \text{ to } 1.549 \pm 0.003\end{aligned}$$

Some of the rock on the dump contains a little hornblende and probably represents the first stage of the gradation into hornblende schist. It is a light gray schist (Spec. 34) with a greenish tinge, consisting of fine-grained quartz, chlorite, sericite, garnets about 1 mm. in diameter, small grains of magnetite, and much disseminated pyrite, which is partly arranged in irregular planes parallel to the schistosity. The hornblende which is not plentiful occurs in dark green crystals ranging up to 2 or 3 mm. in diameter. Examined under the microscope, the smaller garnets have well-defined outlines but the larger ones are usually ragged, and all of them contain included grains of quartz. The magnetite is disseminated in grains and small angular masses showing more or less distinct crystal outline. Pyrite is frequently in contact with magnetite and often occurs in narrow planes or lenses parallel to the schistosity. Small plagioclase feldspars and dark green prismatic crystals of hornblende, with a few grains of titanite, and small inclusions of apatite and zircon, make up the minor accessories.

About 50 yards southeast of the McKenna shaft, a small diabase dike outcrops, but could not be traced any distance. The strike is probably northeast and southwest. It is a medium-grained, dark gray rock with ophitic texture easily recognizable in the hand specimen, and twinning can be seen on the feldspars with the aid of a pocket lens. Pieces of rock found on the dump indicate that a very fine-grained diabase dike, which in places is only 1½ inches wide, was encountered in the underground workings.

The Johnson Mine.

At the Johnson mine, the gossan may be seen outcropping in the road 100 yards south of the shaft, and there is much vein quartz lying on the surface in the same vicinity. A short distance north, there are outcrops of the same knotted schist found on the east side of the ore-body wherever there are exposures. This rock was also encountered in the underground workings, and a thin section was made from a piece of the schist (Spec. 319-A) found on the shaft dump. It is a dark gray, thinly foliated schist with the folia wrinkled by numerous small pseudophenocrysts of garnet and biotite around which they are folded. The garnets are much more plentiful than the biotite crystals, and there is also a little pyrite. Under the microscope the biotite crystals are seen to contain numerous included grains of quartz and in a few instances the flakes are bent or curved, giving the mineral an undulatory extinction. They have no uniform orientation. The ground-mass is composed essentially of quartz and sericite with a little

chlorite, biotite, and very rarely plagioclase feldspar. The quartz occurs in elongated grains interleaved with fine shreds of sericite, all being perfectly oriented parallel to their greatest dimension. Flakes of sericite in the same vicinity extinguish together except where the folia are bent around the pseudophenocrysts, and there they look as though they had been pushed aside by the mineral in its growth, forming lenticular eyes, with quartz usually filling the ends of the lenses. Some of the eyes contain two crystals instead of one, though this is not common. A similar rock (Spec. 307) in which the eyes are formed chiefly of biotite instead of garnet, is found at a somewhat greater distance from the granite. It is described on pages 32-33.

Hornblende schist outcrops in the road less than 100 feet south of the gossan, and a microscopic slide (Spec. 458) was made from some of the rock obtained within 200 feet. In the hand specimen it is a fine-grained, dark green rock, close-textured and slightly schistose, composed for the most part of hornblende, quartz, and chlorite. Under the microscope the rock is distinctly schistose because of the approximate orientation of the hornblende. This mineral is dark green in color, ragged in outline, and only occasionally contains inclusions of the other minerals. The hornblende constitutes about 75 per cent. of the rock mass. Irregular grains of quartz, chlorite, partly if not wholly derived from hornblende, a little plagioclase feldspar, and a few grains of magnetite make up the remaining constituents. In the absence of chemical analyses it is impossible to say whether this rock is igneous or sedimentary in origin, but the manner in which it is interbedded with other schists varying slightly in composition, leads the writer to believe that this schist is more likely derived from a sedimentary rock.

At the mouth of the adit about 150 feet southeast of the Johnson shaft, a fine-grained, dark gray schist is exposed, in which quartz, chlorite, probably hornblende, magnetite, and pyrite are the only minerals coarse enough for megascopic identification. A thin section (Spec. 319-B) was made from a similar rock found on the dump. In the hand specimen it is a fine-grained, compact rock, gray with a slightly greenish tinge. It is slightly banded and contains a little disseminated pyrite, but most of the minerals are too small for megascopic identification. Under the microscope it is seen to consist of quartz, hornblende, soda-lime feldspar, chlorite, and magnetite, the order given being that of relative abundance. The quartz occurs in clear grains showing no granulation and little optical distortion. Hornblende is present in ragged individuals with numerous

inclusions of quartz and magnetite, and varies in size up to nearly 1 mm. in length. The crystals are uniformly oriented parallel to the schistosity. Plagioclase feldspar (probably andesine) is plentiful, and usually shows albite twinning. The chlorite is light green in color and occasionally shows multiple twinning. Magnetite occurs in small irregular grains uniformly distributed throughout the slide.

Another variety of hornblende schist found on the dump is coarser grained (Spec. 320-A). Megascopically it is a dark green schistose rock containing crystals of green hornblende 1 to 2 mm. in diameter, brown biotite, green chlorite, and occasional brown garnets. In thin section the hornblende is light green in color, very ragged in outline, and contains numerous inclusions of the other minerals, principally quartz. It shows extensive alteration to carbonate and chlorite. The biotite has strong absorption, changing from brown to pale brown or colorless, and in places it shows alteration to chlorite. Quartz and soda-lime feldspar (andesine) are present in small grains, partly as inclusions in the hornblende and partly filling interstitial spaces. The feldspars usually show albite twinning. Grains of titanite, magnetite, and occasional rutile needles make up the minor accessories.

Descriptions of the ore-body by men who worked in the mine, and the material found on the dumps, indicate that the ore-deposits at the Johnson mine are essentially the same as at the mines previously described. The ore-body is said to dip toward the northwest at an angle of about 80°. In some of the ore found on the dump pyrite occurs mixed with pyrrhotite and a little chalcopyrite, the gangue minerals being a small amount of quartz and sericite. Fragments from quartz-feldspar veinlets are also present on the dumps. The copper ore that was mined and shipped from this property is said to have consisted chiefly of "rich black copper ore" (chalcocite) found a short distance below the water level, and little or no high-grade copper ore seems to have been found in the lower workings.

The Hudgins Mine.

The country rock at the Hudgins mine, as indicated by outcrops in the vicinity, is exactly the same as at the other mines described above, and there seems to be no essential difference in the character of the ore-deposit. The material found on the dump is not as heavily impregnated with sulphides as at the Johnson and McKenna mines, and most of the ore-bearing schist is much lighter colored. Some of the rock closely resembles the quartz-sericite schist at the London and Virginia and Buckingham

mines. It is a fine-grained, white, lustrous schist in which quartz, sericite, and disseminated pyrite are the only minerals that can be identified with a pocket lens. Other pieces found on the dump are similar but contain a few scattered flakes of biotite.

GENESIS OF THE NEW CANTON ORE DEPOSITS.

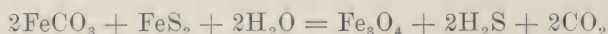
The New Canton ores belong to that class of ore-deposits known as contact deposits, and it is believed that the sulphides which occur impregnating the schists near the contact were derived from the mass of intruded igneous rock that lies to the east. Acid igneous rocks on cooling give off a large amount of water in the form of highly heated vapor or gas, and this water may carry minerals in solution and deposit them where the conditions are most favorable. That this has been the mode of formation of the New Canton deposits is indicated by the facts, brought out in the detailed descriptions, which may be summarized as follows:

1. The location of the ores in highly metamorphic schists close to their contact with an acid igneous intrusive.
2. The extensive alteration of the ore-bearing schists with the production of sericite, chlorite, and garnet.
3. The presence of lenses and veinlets of quartz and feldspar, which in places approach pegmatite in composition and appearance.
4. The association of pyrite, chalcopyrite, pyrrhotite, and magnetite as the principal ore minerals.

As has been stated elsewhere in this report, the intrusion of the granite (granodiorite) was accompanied by a partial segregation or concentration of the more basic minerals in the border portions of the cooling magma, and the extensive metamorphism of the sedimentary rock along the contact. The rocks nearest the granite possibly owe their alteration, which resulted in the production of hornblende rocks, chiefly to heat and pressure, but the alteration of the schists at a somewhat greater distance from the contact, seems to have been due primarily to the heated vapors expelled from the cooling magma. This is indicated by the predominance of the anhydrous minerals, chiefly hornblende, in the rocks nearest the contact; while in the ore-bearing schists, such hydrous minerals as sericite and chlorite were extensively developed. The occurrence of masses of chlorite containing many large garnets, which even under the microscope show no alteration, is difficult to account for if the chlorite was formed entirely as a result of superficial agencies, and, moreover, the inclusions of country rock found in the quartz-feldspar veinlets are all altered to chlorite, biotite,

and garnet. The same solutions that altered the schists and formed the quartz-feldspar veinlets, deposited the sulphide ores, chiefly pyrite. Some chalcopyrite may have been deposited as a primary mineral at this time, but it seems probable that most if not all of the copper was originally deposited as cupriferous pyrite. The sulphides undoubtedly filled any openings that may have been present, and while the schist may have been injected with veinlets and stringers of pyrite, as with quartz and feldspar, most of the sulphide masses, even where purest, give evidence of formation through metasomatic replacement of the schist.

The frequent association of pyrite and magnetite suggests that the latter was formed by the reducing action of pyrite, since siderite is a prominent constituent in some of the knotted slates a few hundred yards west of the contact. Van Hise has called attention to the development of magnetite from iron carbonate on an extensive scale where igneous rocks have been intruded into ferruginous sedimentaries, and gives the following chemical equation as the probable reaction by which the magnetite is produced:^a



The hydrogen sulphide set free by the reaction would aid in the alteration of the schists by combining with the iron derived from the iron-bearing silicates, and it is not improbable that the light color of the ore-bearing schists is partly due to the formation of pyrite at the expense of the dark-colored, iron-bearing silicates.

The primary ore consisting chiefly of pyrite, slightly cupriferous, with perhaps more or less chalcopyrite, had a very low copper content. The high-grade copper ore, such as that obtained at the Johnson mine a short distance below water level, owed its formation to concentration through meteoric agencies, of the copper originally present in the upper portion of the ore-body. Surface waters, entering the ore-body by means of small pores, cracks, and joints, carry oxygen and carbon dioxide in solution which react on the sulphides to form copper sulphate and other more or less soluble salts. The copper salts, being more soluble than the iron compounds formed, are mostly leached out and carried farther down, where the copper is reprecipitated by replacing iron in the fresh sulphides below. As a result of these reactions, oxides and carbonates of copper may be present in the upper, oxidized portion of the ore-body, while the rich sulphurets, such as chalcocite, bornite, and chalcopyrite, occur near the

^aVan Hise, C. R., *A Treatise on Metamorphism*, Monograph XLVII, U. S. Geol. Survey, 1904, p. 838.

water level, and in the deeper portions of the ore-body only the low-grade, primary sulphides are found.

The practical absence of malachite, azurite, and copper oxide from the oxidized portion of these ore-deposits is probably due to the low copper content of the primary ores, the humid climate, and the long period during which the copper has been subjected to concentration. The ore-bodies originally extended much higher above the present surface, and part of the copper contained in the zone of secondary enrichment undoubtedly came from the upward extension of the deposits, which have been removed by erosion during the long period of time which has elapsed since the ores were first formed.

COMPARISON WITH OTHER ORES OF THE DISTRICT.

There is a marked resemblance between the New Canton ores and those at the London and Virginia, and Buckingham mines, the difference being chiefly in the relative proportion of the minerals present. At the latter locality the sulphides, which are apparently not as plentiful, occur chiefly as impregnations in a quartzite instead of a schist, the quartz-feldspar veinlets are more prominent, and the gold content is greater while that of copper is less. The New Canton type of deposit seems to represent one extreme of a gradational series, the typical gold-bearing veins of the district being at the other extreme, with the London and Virginia type intermediate between the two. At the New Canton mines the secondary ores were, in places, rich enough in copper to pay for their extraction, but these ores can not be expected to extend any great distance below the water level, and it is not believed that the copper content of the primary ores is sufficient to make them of value as a source of that metal. While in places high-grade pyrite occurs in the deposits, the greater portion of the ore-body contains a large amount of gangue material, and it is improbable that these mines could be profitably worked at the present time for their sulphur content alone.

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